# SEWAGE AND INDUSTRIAL WAS

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WA

## Special Features

1957 Literature Review, Part III—Research Co
Water Pollution

Nitrogen and Activated Sludge—Symons and Mc

Industrial Public Relations—Bixby

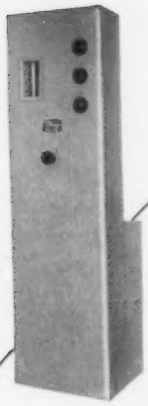
Whey Utilization—Wasserman et al.

Minerals in Waste-Water—Stone and Mer

Operator's Corner
Digester Supernatant, O-R-P for Chlorina

JULY 1958—VOL. 30, No. 7

POSITIVE CONTROL OF MATERIALS IN MOTION



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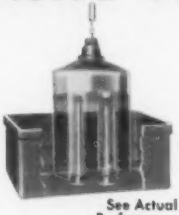

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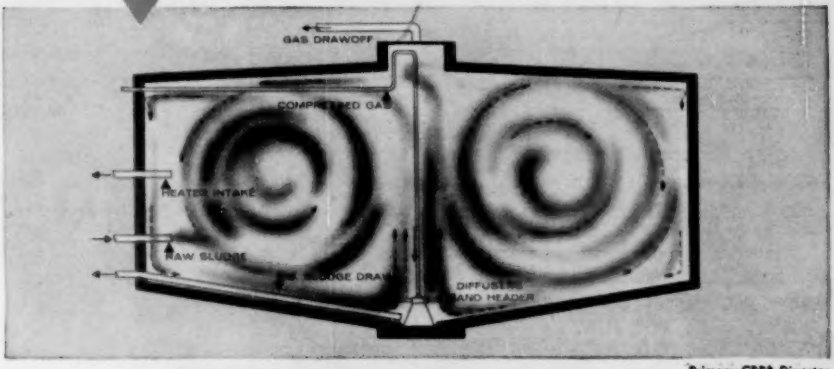


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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works. The Journal was known as *Sewage Works Journal* until January 1950.

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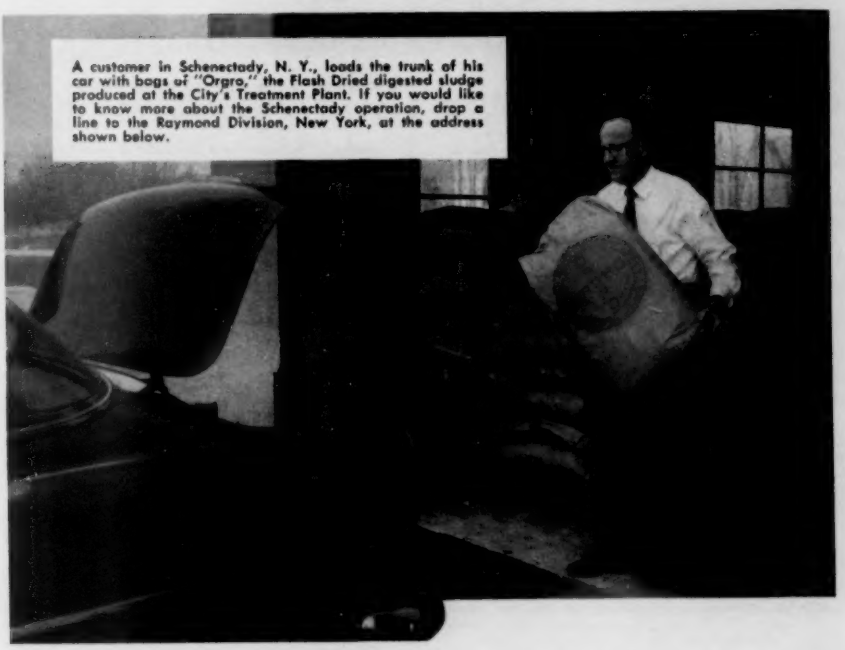
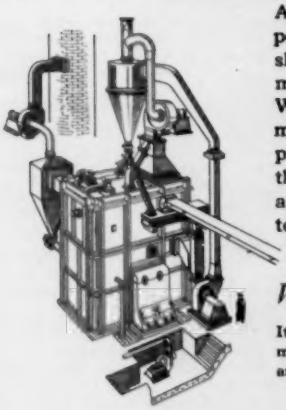

A customer in Schenectady, N. Y., loads the trunk of his car with bags of "Orgro," the Flash Dried digested sludge produced at the City's Treatment Plant. If you would like to know more about the Schenectady operation, drop a line to the Raymond Division, New York, at the address shown below.

# Can you think of a better way to dispose of sewage sludge?



At first glance, the trunk of a car may seem to be a peculiar place to deposit sewage sludge. But when the sludge is dry, sterile and neatly packaged, it can be a marketable commodity rather than a bothersome waste. When uncontaminated with noxious industrial materials, it is an excellent soil conditioner. Its sale produces revenue for the treatment plant, eliminates the nuisances of drying beds, lagoons and ash disposal and, at the same time, renders a service to the people of the community.

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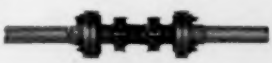
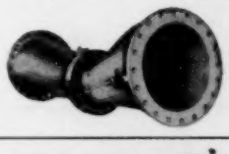
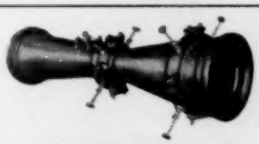
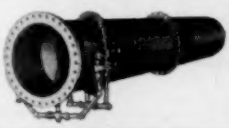
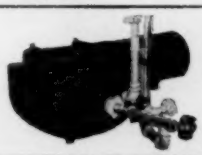
| FLOW CONDITION | | SOLUTION |
|---|---|---|
| NORMAL WATER, AIR OR GAS FLOWS | | TYPE VT—STANDARD VENTURI TUBES<br>Cast iron with bronze bushed main piezometer holes and bronze throat liner. Flanged, bell or spigot ends. Inspection opening at throat. Special metals for high pressures or caustic liquors, corrosive gases, brines, etc. BULLETIN 005 |
| NORMAL WATER, AIR OR GAS FLOWS | | TYPE TG—INSERT TUBES AND NOZZLES<br>Withstand high pressures. Fit inside existing lines . . . permitting light construction. This, plus *short length*, cuts costs. BULLETIN 100 |
| SMALL FLOWS OF WATER, GASES CORROSIVE FLUIDS |  | TYPE TF—MINIATURE VENTURI TUBES<br>Machining to .0005" assures accuracy. Main diameters as low as ½"; throat diameters down to .1". Welded stainless steel models for high pressures. BROCHURE |
| NORMAL SEWAGE, SLUDGE, TRADE WASTES |  | TYPE VTJ—SINGLE TAP VENTURI TUBES<br>Single taps at main and throat have bayonet-type valve for fast cleaning. Absence of pressure belts prevents clogging. Inspection opening at throat. BULLETIN 005 |
| NORMAL SEWAGE, SLUDGE, TRADE WASTES |  | TYPE VS—FOUR TAP VENTURI TUBES<br>Four cleaning valves at main and throat can be operated manually, by air, or hydraulically to keep piezometer holes clear for top accuracy. Two hand holes on each pressure belt and inspection opening at throat. BULLETIN 005 |
| LOW-VELOCITY SEWAGE, HEAVY WASTES |  | TYPE VE—ELLIPTICAL VENTURI TUBES<br>Developed specifically to accurately measure low-velocity sewage, sludge and heavy trade wastes—under low pressures. *Flat top* prevents air binding. *Flat bottom* is self-scouring. Inspection opening at throat. BROCHURE |
| LOW-HEAD SEWAGE, SLUDGE, TRADE WASTES |  | TYPE S—PARABOLIC FLUMES<br>Full 20:1 range for open flows. Accuracy ±2%. Flanged, bell or spigot inlet for 6 to 36" lines. Integral sediment trap, piezometer reamer, gauge glass, direct-reading flow scale. BULLETIN 801 |

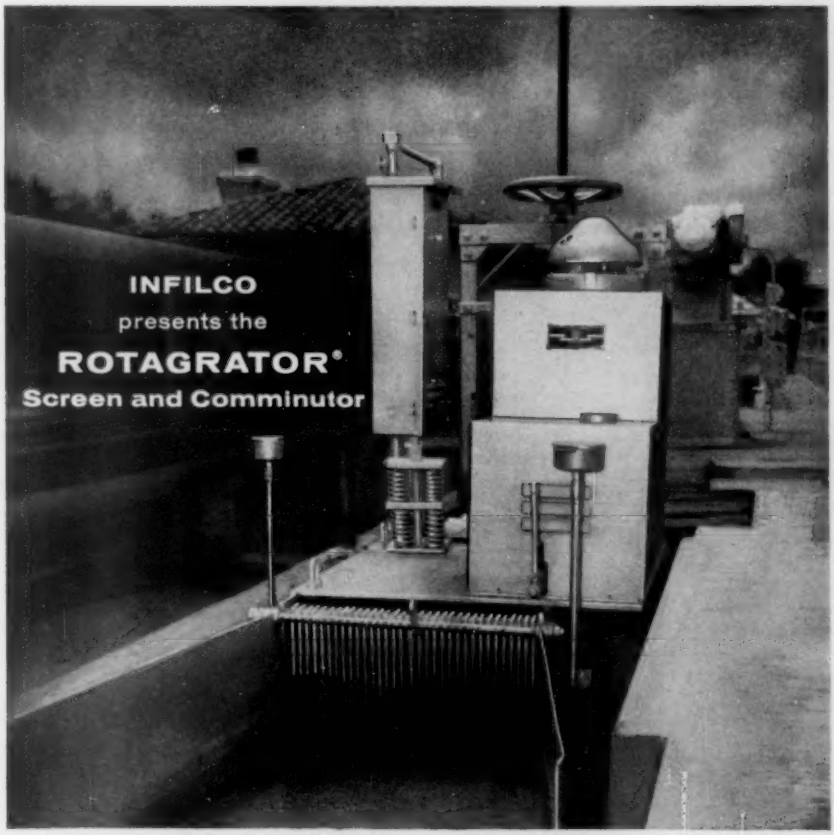
# MEMBER ASSOCIATION MEETINGS

| *Association* | *Place* | *Time* |
|---|---|---|
| Pennsylvania Sewage and Industrial Wastes Assn. | Penn. State Univ. University Park, Pa. | Aug. 13–15, 1958 |
| Georgia Water and Sewage Assn. | Ga. Inst. of Tech. Atlanta, Ga. | Sept. 10–12, 1958 |
| Rocky Mountain Sewage and Industrial Wastes Assn. | Cosmopolitan Hotel Denver, Colo. | Sept. 15–17, 1958 |
| South Dakota Water and Sewage Works Conf. | Franklin Hotel Deadwood, S. Dak. | Sept. 17–19, 1958 |
| Kentucky-Tennessee Industrial Wastes and Sewage Works Assn. | Hotel Peabody Memphis, Tenn. | Sept. 22–24, 1958 |
| Oklahoma Water, Sewage and Industrial Wastes Conf. (Short Course) | A and M College Stillwater, Okla. | Sept. 24–25, 1958 |
| Pacific Northwest Sewage and Industrial Wastes Assn. | Davenport Hotel Spokane, Wash. | Sept. 25–27, 1958 |
| Missouri Water and Sewerage Conf. | Hotel Governor Jefferson City, Mo. | Sept. 28–30, 1958 |
| North Dakota Water and Sewage Works Conf. | Ray Hotel Dickenson, N. Dak. | Oct. 1–3, 1958 |

## THIRTY-FIRST ANNUAL MEETING

**Federation of Sewage and Industrial Wastes Associations**
**in conjunction with**
**Michigan Sewage and Industrial Wastes Association**
**Sheraton-Cadillac Hotel, Detroit, Michigan**
**October 6–9, 1958**

| | | |
|---|---|---|
| Florida Sewage and Industrial Wastes Assn. | Golden Gate Hotel N. Miami Beach, Fla. | Oct. 19–22, 1958 |
| West Virginia Sewage and Industrial Wastes Assn. | Daniel Boone Hotel Charleston, W. Va. | Oct. 22–23, 1958 |

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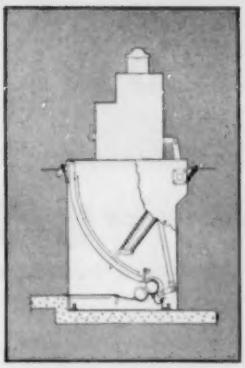
No matter what the load may be, the unit operates continuously without harm to the mechanism, because of its rugged construction and safety devices incorporated in its design.



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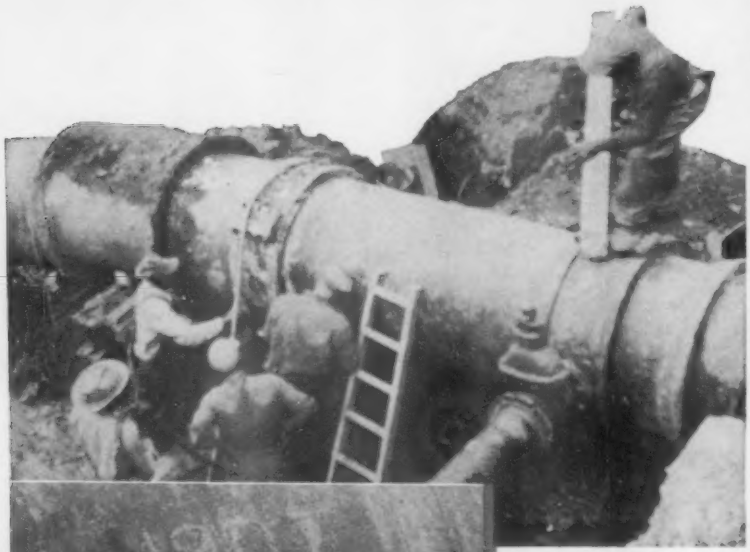
# ANY PIPE CAN PROMISE...



**50 YEARS YOUNG!** This 36" Cast Iron Pipe feeder main was installed in 1907. Taken up in 1954 because of relocation project, it was relaid in 1956 for a bypass line around new highway interchange.

Close-up of section of above pipe 1,958 feet of which was cleaned and reused.

MODERNIZED **cast iron**

# CAST IRON PIPE PERFORMS!

## What other pipe offers you LONG LIFE + STRENGTH + HIGH FLOW CAPACITY?

**Don't doubt when you buy pipe—specify cast iron and be sure of...**

1. **LONG LIFE...** 42 North American cities are still using cast iron water mains laid 100 years and more ago. Hundreds more have passed the 50 year mark.
2. **BEAM STRENGTH...** Cast Iron Pipe is inherently tough... stands up under heavy traffic load, soil displacement and disturbance.
3. **HIGH FLOW CAPACITY...** Cement lined cast iron pipe and fittings will not tuberculate... delivers a full flow for the life of the pipe.
4. **EXTERNAL LOAD RESISTANCE...** 6" Class 150 Pipe withstands a crushing load of 17,900 pounds per foot... nearly 9 tons.
5. **CORROSION RESISTANCE...** Cast Iron Pipe effectively resists corrosion... vital factor in its long life and dependability.
6. **TIGHT JOINTS...** A full range of leak-proof, low cost, easy-to-assemble joints for pipe and fittings are available for all conditions.

You've read and heard thousands of words—all selling pipe.

But make no final choice before you ask this simple question: What pipe offers you not one, not two but *all* the factors that spell long, trouble-free life and dependability.

The answer is... cast iron pipe. Performance made it... and performance keeps it... America's No. 1 Water Carrier.

Its service record *proves* it!

THE MAN WHO CHOOSES CAST IRON PIPE TODAY WON'T PAY FOR IT AGAIN TOMORROW!

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Cast Iron Pipe Research Association
Thos. F. Wolfe, Managing Director
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**pipe** FOR MODERN WATER WORKS

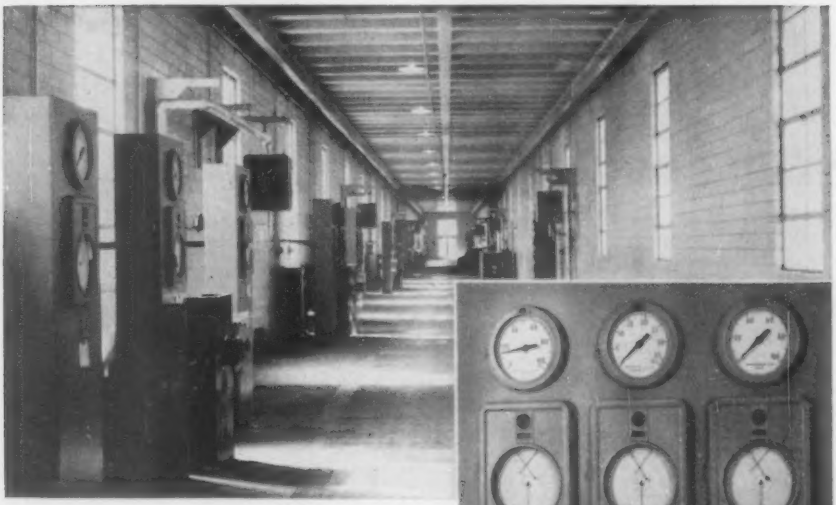

Figure 1—Aeration gallery, showing Bailey Meters which measure the aerated sewage, air, and return sludge.

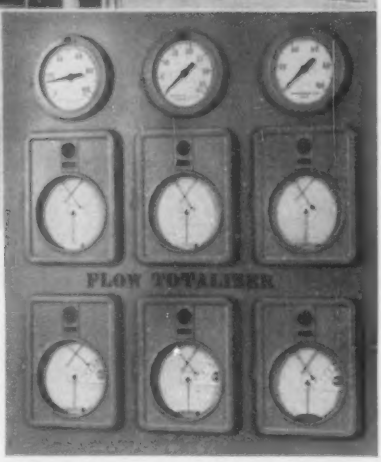


Figure 2—Bailey Electronic Flow Totalizers sum up total sewage, air, and sludge flows measured at individual gallery stations, showing at a glance the plant's performance.

Havens & Emerson—Consulting Engineers

# FLOW TOTALIZATION – at Southerly Sewage Treatment Plant

Instantaneous plant performance and operating trends are continuously available to supervisors and operators through Bailey's Electronic Flow Totalizer.

The new 32 MGD addition to the Southerly Sewage Treatment Plant, Cleveland, Ohio is equipped with Bailey Flow Meters, Integrators, Indicators, and Recorders.

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**In Canada—Bailey Meter Company Limited, Montreal**

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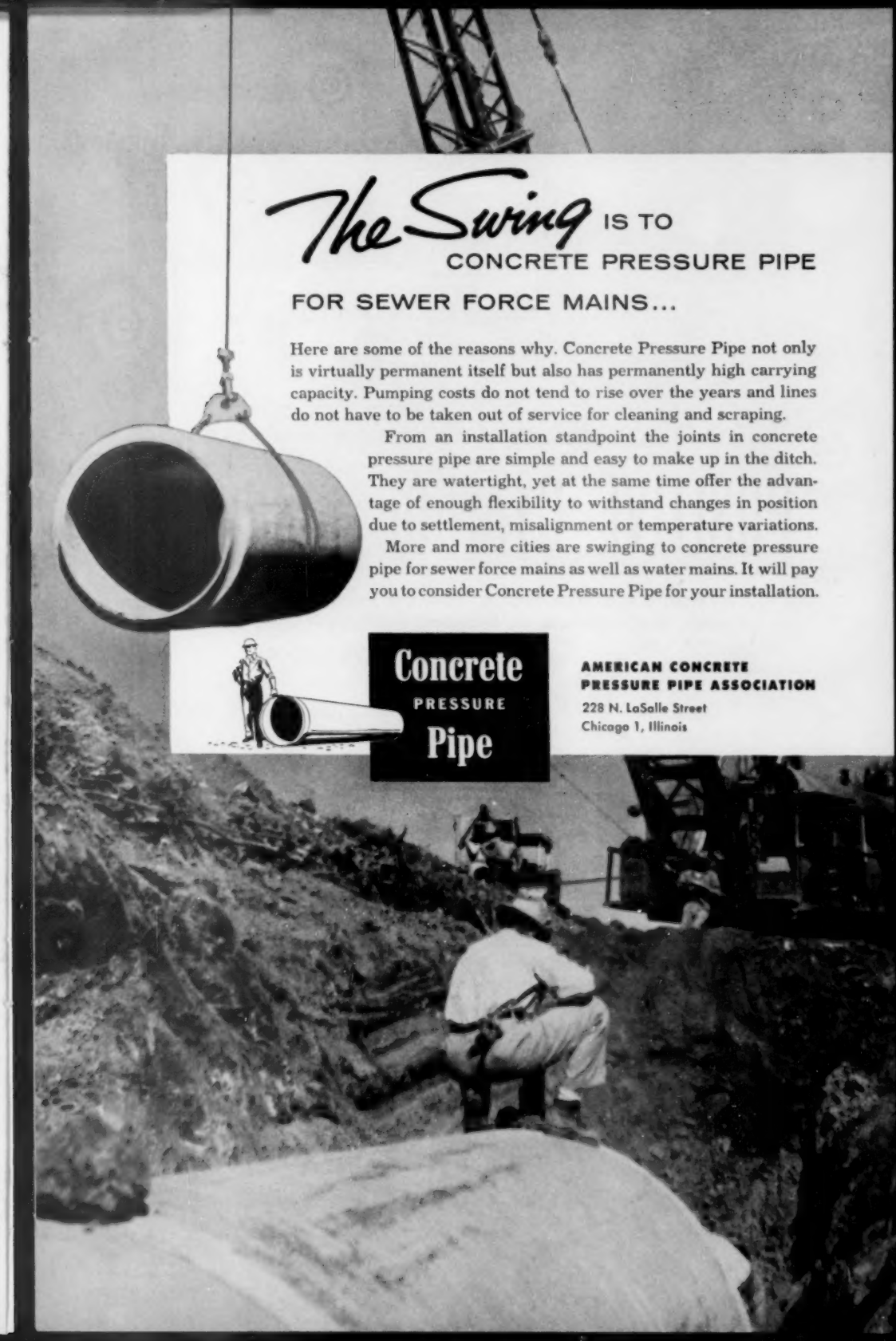
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FOR SEWER FORCE MAINS...
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More and more cities are swinging to concrete pressure pipe for sewer force mains as well as water mains. It will pay you to consider Concrete Pressure Pipe for your installation.
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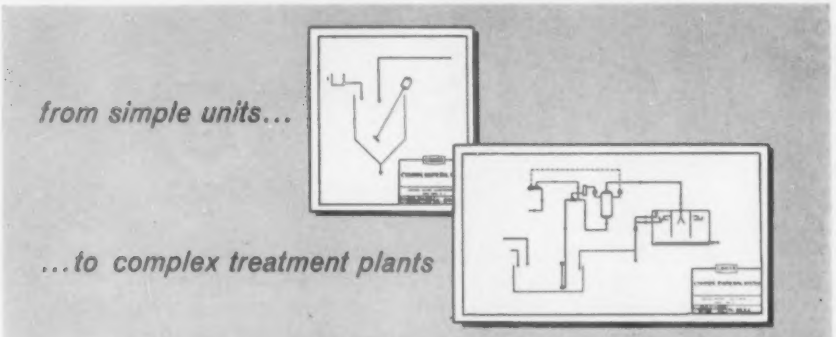


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The complete line of Graver equipment for the treatment of cyanide *and all other plating wastes* includes Reactivators®, Rota-Rake® Sedimentation Basins, Ion Exchangers, and specially designed batch treatment units with all controls and accessories.

Whether your problem is cyanide, chromate, acid, alkali or any combination of wastes, Graver know-how, based on years of successful waste treatment experience, will provide the perfect answer in the form of integrated, efficient systems job-engineered to individual plant needs.

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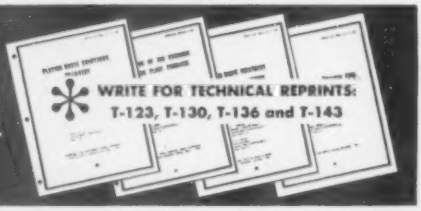

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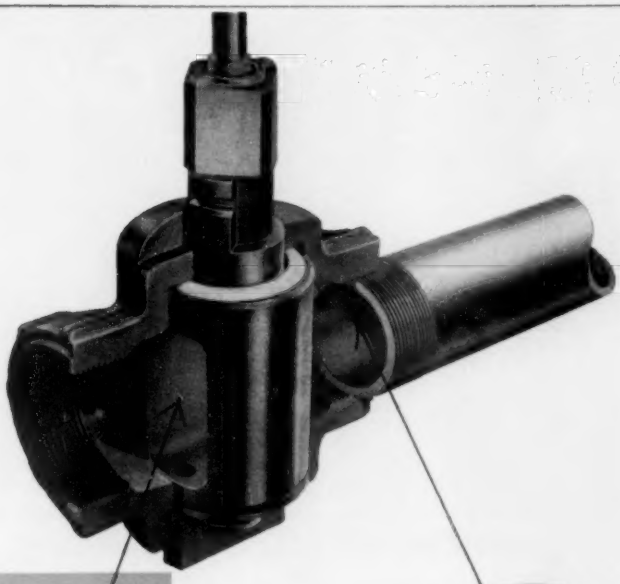

# This Rectangle Equals This Circle!

## acf Lubricated Plug Valves give you minimum turbulence ... minimum pressure drop

The shape and size of the rectangular ports of ACF Lubricated Plug Valves combine flow efficiency of the pipe with compact plug valve design.

The flow of fluid from pipe through plug is unimpeded: entrance chamber design reduces turbulence to a minimum, and loss of head pressure is kept to a minimum.

**Other advantages:** tight sealing without wedging or sticking; Teflon* head gasket; quick quarter-turn opening and closing; precision lubrication; knife-edge shearing action of the plug.

For efficiency, for easy operation, for low maintenance and long life, specify the industry's finest—ACF Lubricated Plug Valves.

*Du Pont's tetrafluoroethylene resin.

*On Hand*

Order ACF valves from your industrial jobber or supply store. Sizes: ½-inch through 30-inch. Pressures: 125 lbs. WOG to 900 lbs. WOG in semi-steel, ASA 150 and ASA 300 in carbon steel. Rectangular, round, V and diamond ports. Bronze and aluminum valves available for use where indicated.

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**W-K-M's *Creative Engineering*** can assist you with any special problem. If it involves flow of fluids or gases through valves, check first with W-K-M.

5804

# REMOVE GRIT

Easily—Thoroughly—at Low Cost

## COMPLETE EQUIPMENT
*to do the complete job!*

PROVIDES CONSTANT OPTIMUM VELOCITY
POSITIVE ADJUSTMENT FOR VARYING FLOWS
HYDRO-DYNAMIC WASHING
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**FLOW CONTROLS**—exclusive Camp Channel Section and Regulator* maintain constant optimum velocity for effective grit settling, regardless of rate of flow through plant. Velocity can be easily and instantly adjusted to meet changing conditions. Minimum head loss.

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***Write for Bulletin No. 249B***

*Technical Supplement "CR", containing complete design data on the* AMERICAN CAMP GRIT CHANNEL *and* REGULATOR, *is available on request with Bulletin 249B.*

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**Contractors:** C.F.W. Construction Co., Inc.; Sterrett Construction Co.

C 458-1A

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The Fairbanks-Morse motor has a lifetime Copperspun rotor, cooled and lubricated by water. In combination with F-M—Pomona pump bowls, these wet stator motors give unbeatable pumping performance over a wide range of volume, depth and pressure requirements.

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**Under water, too, Cen-Vi-Ro saves money!**

The precision fit and unique joint harness cut the diver's work to a minimum.

The absence of metal in the joints pays real dividends in long life.

Job pictured is a pressure sewer at Long Key, Pinellas County, Florida.

**P.S.** Write for details of the big subaqueous pipe we made in Managua, Nicaragua, last summer!

*Engineer:* Russel & Axon, Daytona Beach
*Prime Contractor:* J. E. Milam, Birmingham
*Sub Contractor:* Powell Brothers, Ft. Lauderdale

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*Another Quality Product from*

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Check the list of General Chemical's dry or liquid alum producing locations at left. Chances are one is convenient and close to you. In addition to these plants, our chain of warehouses across the country makes stocks of dry aluminum sulfate readily available in every major center of commerce. Write or phone for information on how we can serve you.

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**This distillery was caught in a squeeze**

**between the need to prevent stream pollution**

**and the absence of municipal sewage facilities.**

**Solution: a LINK-BELT Bio-Filtration plant providing . . .**

# pollution control — pure and simple

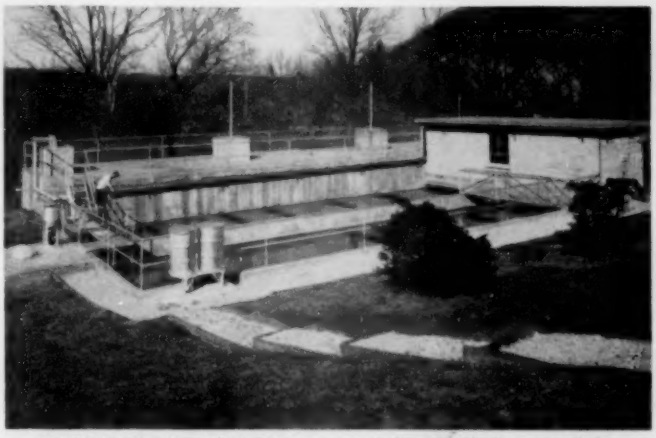
Like many another plant which has located at an outlying site, National Distillers Products Company (Frankfort, Ky.) found it necessary to treat its own process and sewage wastes. Because the only outlet is a nearby stream of insufficient waste absorption capacity, it was found essential to treat the wastes in order to avoid any stream pollution hazard. And the solution—a highly effective one — was found in a simple Link-Belt bio-filtration system.

## Pattern for Pollution Control

In taking on any problem of this nature, the first move is to determine the nature of the wastes . . . the ability of the stream to dilute, purify and carry them away safely. A modern, well-equipped Link-Belt laboratory is maintained to assist your engineers.

Next step: a study of the processes from which the wastes originate in order to check or reduce the pollution at its source. As a result, it is often possible to reduce the cost of treatment facilities necessary by segregating polluting wastes from non-troublesome discharge.

Armed with this complete data, Link-Belt is able to make an accurate and unbiased recommendation. Whatever treatment equipment is indicated —screens, mixers, collectors, conveyors, drives—there's an economical answer in the broad Link-Belt line.

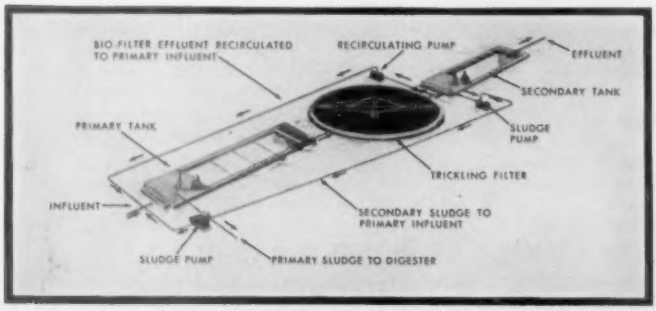


**BIO-FILTRATION PLANT** is Link-Belt's answer to National Distillers' stream pollution problem. Link-Belt primary and secondary Straightline sludge collectors and Straightline scum breaker assure thorough solids removal. A similar system was furnished by Link-Belt in 1949 for another National Distillers plant.

## Experienced Source

Link-Belt invites the opportunity of working with your own engineers, chemists and consultants in planning a waste treatment system for your plant. A background of over 35 years in sanitary engineering includes not only industrial wastes, but large municipal water and sewage treatment plants as well. Whether your chief concern is the reduction of pollution, recirculation of process water or the recovery of salable by-products — you can be sure of a system tailored to your exact needs, operating at lowest cost, and built to last. Your nearest Link-Belt office can give you full details on Link-Belt equipment.

You'll also be interested in our 20-minute color-sound film, "Pure and Simple"—lent on request for viewing by your group.




**TYPICAL LINK-BELT SINGLE-STAGE BIO-FILTRATION PLANT**—similar to the system at National Distillers—consists of primary settling, biological trickling filter and secondary settling. The filter acts as the source of oxygen for micro-organisms and the settling tanks serve for coagulation as well as settling.

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**Professional Sanitation Engineers say:**

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# 3 top contractors tell how Transite Sewer Pipe helped keep installation costs low on the Allegheny County Sanitary Authority sewage project (Allegheny County, Pa.)

"Transite saved us considerable labor especially when we were working in 18- to 28-foot trenches . . ."

says W. R. Davies, W. R. Davies Company
Pittsburgh, Pennsylvania

W. R. Davies Co. installation.

"For the Allegheny County Sanitary Authority we used Transite Pipe for Sanitary Sewers because it is faster to install, lighter, and more readily handled than the other materials specified as alternates. Transite saved us considerable labor especially when we were working in 18- to 28-ft. trenches.

"Another part of our 'Authority' contract included the installation of 5,300 feet of Domestic Water and Fire lines at the 150 MGD capacity Pittsburgh Sewage Treatment Plant. We used Transite Pressure Pipe for this entire job. Our costs were low because it is faster to install."

---

"In a remarkably short time, our men installed two miles of Transite . . . even though they worked below the adjacent river level . . . and between railroad tracks and one of the most congested highways in the county . . ."

says P. A. Benintend, Ben Construction Company
Pittsburgh, Pennsylvania

"For the Allegheny County Sanitary Authority Contract, Transite's ease of installation . . . sure coupling . . . and 13-foot lengths saved money for us in over-all installation. In a remarkably short time, our men installed two miles of Transite Sewer Pipe and force mains, even though they worked below the adjacent river level to install the force main—and between railroad tracks and one of the most congested highways in the county to install the sewer. Speed of installation plus prompt delivery enabled us to finish the job well before the required completion date."

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"We installed Transite Sewer Pipe in some of the toughest locations on this job."

says D. C. Rothey, Project Manager
Harrison Construction Company
Pittsburgh, Pennsylvania

"In our stretch down along the Allegheny River we were constantly 5 to 14 feet below normal pool stage level. Final inspection revealed no infiltration."

*Transite Sewer Pipe installations on the $100-million Allegheny County Sanitary Authority Project. Shown here is part of Harrison Construction Co. contract.*

Ben Construction Co. installation.

## How TRANSITE PIPE answers your two most important problems in sewer installation and operation!

IN INSTALLATION, your big problem is time. For the longer it takes to complete a "tight" installation the more it costs . . . the more annoying the problem of torn-up, detoured streets. And this is where Transite® pays its way in time-saving alone. Its lightweight, long lengths and quickly, *surely* assembled Ring-Tite® Coupling speed every step of installation.

In operation, infiltration and root-clogging can be even more costly. But they're problems that Transite's Ring-Tite® Coupling was designed to solve. Rubber sealing rings, tightly compressed between sleeve and pipe, give you a tight, long-lasting joint that locks out roots . . . seals out unwanted ground water.

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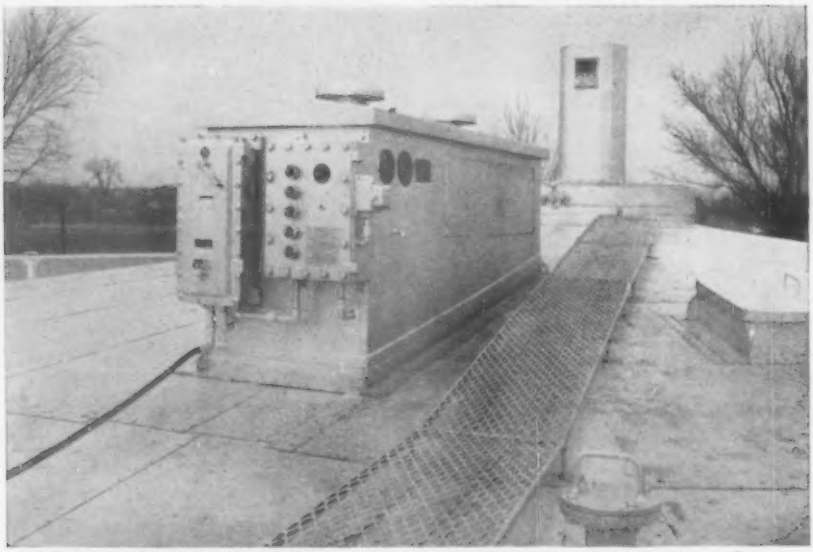


*P.F.T.-Pearth Gas Recirculation System. Warren & Van Praag, Consulting Engineers, Decatur.*

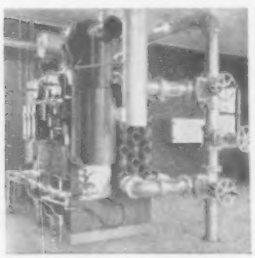
# Decatur, Illinois installs complete modern P.F.T. "Controlled Digestion" system

Unusual industrial and population growth has called for the modernization and expansion of Decatur's sewage treatment plant three times in recent years. Each time Decatur has selected P.F.T. equipment.

The P.F.T. equipment furnished for the most recent expansion is a new digestion system which includes: a 70′ P.F.T. Floating Cover with prefabricated aluminum roofing; the P.F.T.-Pearth gas recirculation system and Model 750 Digestion Heater and Heat Exchanger shown; plus a complete new system of gas piping with P.F.T. gas safety equipment.

The P.F.T.-Pearth gas recirculation system includes a gas compressor rated to deliver 150 cfm at 10 psi powered with a 10 hp motor. Controls are provided to automatically discharge to each of 4 peripheral discharge wells in sequence.

P.F.T.-Pearth gas recirculation provides the most effective means of controlling scum formations. This allows the use of the full Digester capacity. Combined with close temperature control with a P.F.T. Heater, rapid and complete digestion is assured. Decatur's new "controlled digestion" system is now geared to meet the needs of this fast growing community.



*Decatur's new P.F.T. No. 750 Gas Fired Heater and Heat Exchanger, with accessory group B controls, provides full automatic digester temperature control.*

P.F.T.

waste treatment equipment exclusively since 1893

**PACIFIC FLUSH TANK CO.**

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# SEWAGE AND INDUSTRIAL WASTES

*Journal of the Federation of Sewage and Industrial Wastes Associations*

**Volume 30** **July 1958** **Number 7**

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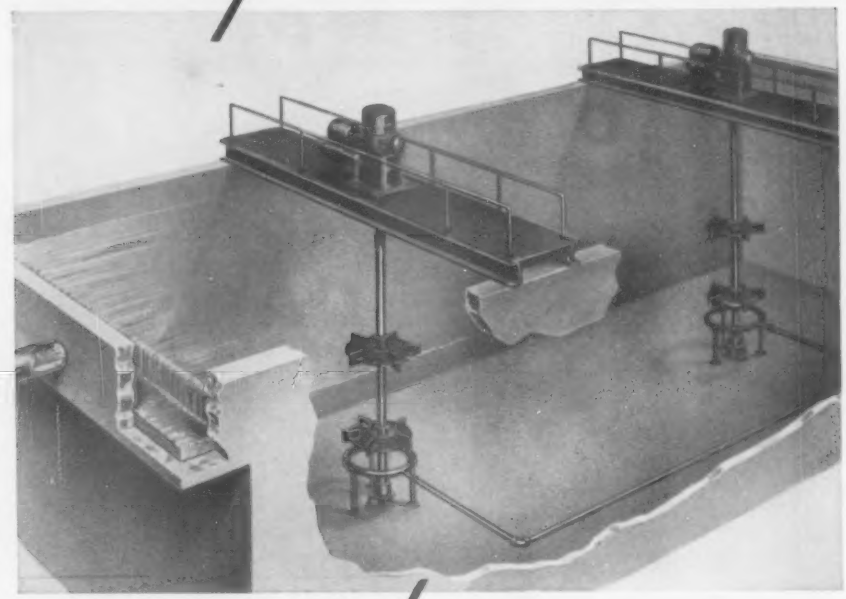

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# 1957 Literature Review

## A REVIEW OF THE LITERATURE OF 1957 ON SEWAGE, WASTE TREATMENT, AND WATER POLLUTION

By H. Heukelekian, *Chairman*, R. Manganelli, *Vice-Chairman*, H. Amberg, E. J. Berg, R. A. Canham, C. H. Connell, W. E. Dobbins, G. P. Edwards, M. B. Ettinger, D. G. Foulke, T. deS. Furman, I. Gellman, A. E. Griffin, H. G. Harding, R. D. Hoak, W. M. Ingram, P. W. Kabler, M. Katz, F. W. Kittrell, L. J. McCabe, P. H. McGauhey, W. A. Moore, P. K. Mueller, R. Porges, E. R. Roth, R. C. Specht, A. J. Steffen, C. Straub, C. M. Tarzwell, G. H. Teletzke, W. W. Towne, H. A. Trebler, E. C. Tsivoglou, and R. L. Woodward

*Committee on Research, Federation of Sewage and Industrial Wastes Associations*

This last of three sections of the review covers water pollution. The first section, dealing with analytical methods and sewage, was published in the May 1958 issue of This Journal. The second section, on industrial wastes, including radioactivity, appeared in the June 1958 issue of This Journal.

## Water Pollution

### BIOLOGY

#### Pollution Surveys and Investigations

Cooperative state-industry stream studies are being carried out on several rivers of Wisconsin (204). Chemical, physical, and biological conditions in the Fox River below Lake Winnebago were studied intensively. It was found that some stretches of the river may receive as much as 400 tons of organic matter per day; that sludge deposits are formed, and that in some sections DO is reduced to critical levels. Graphs of DO concentrations indicate that lethal levels for fishes are reached in one area.

A Fish and Wildlife Service report (184) points out that pollution of the Delaware River in the Philadelphia area prevents its use by shad as a spawning and nursery area. Pollution has been most severe on the runs of shad in recent years, affecting spawners during the upstream migration and both young and adults on their downstream migration. The Delaware River fishery for shad has declined from a

peak production of 19 million lb in 1896, to a level at which it is economically unfeasible for fishermen to operate. Apparently the decline is due primarily to an oxygen block between Torresdale and Marcus Hook where the DO falls to zero or near zero in the late summer. The period of low flow, low DO, and downstream migration of juvenile shad occur simultaneously in September and October. There is also a high mortality of spawned-out fish as shown by the fact that only 1.7 per cent of adults are repeat spawners while in other Middle Atlantic streams the percentage of repeaters varies from 34.6 to 51.

Many statewide surveys are being carried out through the use of Dingell Johnson funds. These serve to indicate the condition of streams and of fish populations. Hulsey (86) reports that the Red River watershed is the most seriously polluted area in Arkansas. Oil field wastes pollute 415 miles; silt and shifting sand, 136 miles; paper mill wastes, 110 miles; phenolic compounds, 25 miles; and barite mine seepage waters, 20 miles. The Arkansas River watershed is the second most polluted with silt and shifting sand being the main pollutant. In the Russell and Levisa Forks of the Big Sandy River in Kentucky, pollution is due to coal washings, acid mine waters, sewage, oil, silt, and sawdust. In some sections of the streams coal deposits are four feet deep (101). Electric seining operations indicated that 45 species of fish were present in these streams.

A survey of the Bhadra River of India (45) indicated extensive biological effects of industrial pollution. Fish found dying below paper mills had not been feeding as their digestive tracts were empty. A strong, mixed odor of sulfides, sulfonates, and chlorine emanated on opening these fishes. Heavy sewage pollution in the Schliersee (Germany) brought about a deterioration in condition and a decrease in numbers of the fish (169). The fish which were examined showed signs of starvation. Vivier (196) found that a rayon plant on the Somme River in France increased the mineral content of the stream and encouraged slime growths which at times broke loose and caused sudden fish kills. The discharge of organic wastes into lakes brought about a decrease in the oxygen content of the deeper waters and caused the near disappearance of salmon in Lake Eguzon and Lake Annecy. Lake Leman is affected most by the sewage of Lausanne which has caused a putrid slime deposit on the bottom about 60 cm deep.

Hawkes (75) presents and illustrates the use of a biological method of classifying the pollution of streams. He stresses the need for complementary biological and chemical examinations in all surveys of pollution and points out that biological examinations have shown rivers to be seriously polluted by toxic substances which were only subsequently detected by chemical tests that were not practiced on a routine basis. The Freshwater Biological Association (British) in its 23rd Annual Report describes its continuing studies of pollution and the aquatic environment (8). These studies deal with water movements in stratified lakes, the source of dissolved solids, factors governing the abundance of algae, composition of lake muds, and population studies of fishes and invertebrates.

In Great Britain there are several river boards which make annual reports on their surveys and investigations. These reports contain much valuable information on the effects of pollution and the benefits of various abatement methods. In their 1956 report (5) the Bristol Avon River Board gives information on water use, floods, waste discharges, pollution abatement, stream classification, waste treatment, fisheries, and toxicity.

Research activities in Great Britain were summarized by Beak (17) who pointed out that the research program is shaped to meet the requirements of

the 1951 River Pollution Prevention Acts, with special emphasis on standards of purity to be established. One team has been carrying on fundamental research on the toxicity to fish of various chemicals, particularly cyanides, carbon dioxide, and ammonia. Another team has been carrying on field studies of pollution biology, particularly as pertains to fishes. Reis (158) reports that in Ohio, the Division of Wildlife is responsible for the protection and preservation of wildlife and thus the majority of their studies are concerned with fish kills. An intensive study is being made of the effects of acid mine drainage in the Racoon Creek basin and possible corrective measures are under test. Studies are under way on the Little Miami River to determine improvements, resulting from sewage treatment.

In British Columbia, Waldichuk (198) states that studies of the effects of wastes from forest products industries on the marine environment are being stressed. Neil (141), in Ontario, indicates that the most intensive investigation has been on the Spanish River where it was found that the deposition of wood fibers was of prime importance in the elimination of fish food organisms over an extended area. In this same river the mining industry has also created problems due to ore pulverizing wastes which have produced turbidity and unstable bottom conditions. The mining of uranium ores has added new problems; namely, highly acid wastes and toxic metals. Methods for the control of blue-green algae by the removal of phosphorus have been developed and tested.

Routine stream surveys are now complete in Wisconsin and more intensive studies are now being made on the major waterways. These have indicated that studies during the winter period are of importance (129).

A cooperative program of investigations in water pollution biology (200) is being carried out in Oregon. Complementary field and laboratory research designed to provide basic information on pollutional problems in fresh and marine waters is under way. Current field studies include physical, chemical, and biological investigations of polluted streams and studies of small streams, experimentally subjected to controlled pollution. Artificial stream studies are being used to evaluate the effects of low-level pollution and studies are in progress on the influence of DO upon the survival, development, growth, activity, and movement of fresh-water fishes.

The relation of the various fish and game programs of the Fish and Wildlife Service of the U. S. Department of the Interior to the pollution problem was described by Meehan (131). Acid mine drainage, mining wastes, oil pollution, lumbering operations, pesticides, water development projects, and domestic and industrial wastes all may have adverse effects on large segments of wildlife populations. In the Missouri Basin, wastes from the processing of agricultural products are the main pollutants. Other sources of industrial wastes are oil fields, refineries, steel mills, and chemical plants. An unusual fish kill in the Yellowstone was directly occasioned by aerial spraying with DDT to control spruce budworm in the headwater areas (140).

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### Fish Kills

Burden (24) reports that the use of a 30 per cent DDT concentrate in an emulsifiable oil with 0.5 per cent "Lissapol" as a spray to control *Tanytarsus lewsii* in the Nile above Khartoum, resulted in an extensive fish kill. *Labea* were killed in 8 hours and *Synodontis*

in 36 hours. Low oxygen levels during the night and early morning hours due to excessive growths of aquatic vegetation were responsible for heavy fish mortalities in Madras State (India) (30). A similar kill in a temple tank resulted from a heavy growth of *Microcystis aeruginosa* (193). Methods for the investigation of fish kills and steps to be taken when such a kill occurs are outlined by Liebmann (117). In their "Fish Conservation Highlights of 1956" Stroud and Seaman (181) list damage to fish populations throughout the country by various pollutants. Insecticides are becoming of increasing importance in fish kills.

## Water Quality Criteria for Aquatic Life

### *General*

Since the purpose of water quality criteria for aquatic life is to maintain conditions which are favorable for aquatic organisms they must be based on knowledge of the environmental requirements of these organisms. While much is presently known concerning the environmental requirements of the aquatic biota much remains to be learned. Ecological, life history, and environmental studies are, therefore, pertinent and valuable. Studies carried out in Belgium and reported by Huet (85) have led to the conclusions that (a) alkaline waters are most favorable for fishes; (b) the optimum pH is between 7.0 and 8.0, although values of 5.0 to 9.0 are tolerated; (c) water passing over granite rocks is usually acid and not favorable for breeding; (d) DO content is very important and should be fairly stable throughout the year; (e) trout require more oxygen than do carp and tench; and (f) the optimum water temperature for trout breeding is 15 to 17°C and for carp, 20 to 25°C. A study of mayflies in Douglas Lake, Michigan (125), has shown that *Hexagenia* nymphs are limited by the oxygen concentration to that portion of the mud bottom above the level of the hypolimnion.

In a general discussion of the subject, Tarzwell (185) states that while much remains to be learned, enough information is now at hand for the setting of tentative criteria. It is suggested that pH values should not fall below 5.0 or exceed 9.5, but for good production they should be maintained between 6.5 and 8.5; that for salmonoid fish 6.0 ppm of DO is desirable; that for a well rounded warm water fish population, DO levels should not fall below 5.0 ppm for more than 8 hr out of a 24-hr period, and at no time should they fall below 3 ppm while for coarse fishes they may drop to 2 ppm; for warm water fishes temperature should not exceed 93°F in the northern portion of the country or 96°F in the south, and for trout best production is obtained in streams having summer temperatures of 60 to 68°F. It is suggested that the amount of toxic wastes which can be added to a specific stream should be determined in each case by means of bioassay.

### *Suspended Solids and Turbidity*

Studies in Oklahoma as described by Buck (23) revealed that high turbidities reduced the growth and yield of bass and bluegills and favored the production but not the growth of channel catfish. Clear reservoirs attracted more anglers and yielded greater returns per unit of fishing effort as well as more desirable species of fishes. Experiments in clear ponds with turbidities less than 25 ppm, intermediate ponds with turbidities from 25 to 100 ppm, and muddy ponds with turbidities over 100 ppm, showed that the average total weight of the fish in the clear pond was 1.7 times that from the intermediate pond and 5.5 times that from the muddy pond. Wilson (207) reviewed the literature on the destruction of aquatic life by turbidity and silt and presented evidence of lowered productivity due to the screening out of light

and the abrasive and smothering action of sediment on the bottom fauna and fish eggs.

*Temperature*

Experiments to determine the effects of temperature on the respiratory movements of carp indicated that the upper lethal temperature is lower for the older heavier carp than for the smaller younger fish, which showed little change in respiration rate over a temperature range of 15 to 35°C (134). Experiments with guppies by Gibson and Hirst (65) have shown that in fresh water the optimum temperature range for growth is 23 to 25°C and that growth in 25 and 50 per cent sea water is greater than in fresh water. The upper temperature threshold for the normal development of Chinook salmon eggs was found by Combs and Burrows (37) to be 57.5 to 60°F, while the lower threshold was 40 to 42.5°F. It has been experimentally demonstrated by McLeese (128) that lobsters can be acclimated to certain temperatures, acclimatization for transfer from 14.5 to 23°C being completed in 22 days. Moulting lobsters are less resistant to high temperature, low salinity, and low DO than are hard-shelled lobsters. The upper lethal temperature was raised by an increase in thermal acclimatization, lowered by a decrease in the level of oxygen acclimatization, and lowered by acclimatization to reduce salinity.

*Dissolved Solids and pH*

Since the war industrial plants on the Werra River of Germany have been discharging large amounts of chlorides and have brought about fish kills (170). In 1949 these fish kills were positively correlated with the increase in the salt content of the river water. Fish that were moribund recovered when placed in polluted water that was diluted 30 per cent with tap water. Fish kills occurred in winter when the salt content exceeded 12,000 ppm. The next spring surveys showed that fish were absent from the river immediately below the industrial concentration. The resistance to salinity is greater at lower temperatures. The insect larvae disappeared from the more saline regions and there was a reduction of fish food organisms.

A year-round study by Clemens and Finnell (34) was made of a prairie stream polluted with brine wastes from oil wells and in which the concentration of chlorides ranged from 20,000 ppm at the headwaters down to 100 ppm farther down stream. The 34 species of organisms found in the stream throughout the year are classified according to their chloride tolerance. Fish were present only in the section having chloride concentrations up to 1,000 ppm.

*Dissolved Oxygen and $CO_2$*

Experiments in Germany (91) were carried out to determine the respiration of aquatic animals at different rates of flow and the relation of the lethal oxygen tension to the rate of flow and of the oxygen demand of larvae to the oxygen tension and the rate of flow. In experimental studies with caddis fly larvae by Philipson (152), it was found that larvae normally inhabiting riffle areas are readily immobilized at a relatively high oxygen concentration in still waters but can tolerate low oxygen concentrations in flowing water comparable to levels tolerated by the species found in pool areas.

Prosser *et al.* (155) found that goldfish acclimated for several days to low DO level, could withstand considerable lower DO concentrations than goldfish which had not been acclimated. The goldfish acclimated to low oxygen had increased hemoglobin and higher red cell counts and a lowering of the oxidative activity of some tissues. Other studies by Burdick *et al.* (26) showed that the minimum lethal concentration of DO for yellow perch during short

exposure periods varied from 0.77 ppm at 53°F to 1.34 ppm at 70°F, as determined by turnover in a sealed container. It has been shown and reported by Alabaster *et al.* (2) that concentrations of $CO_2$ which sometimes occur in polluted streams can more than double the minimum concentration of DO necessary for the survival of half the rainbow trout during a 24-hr exposure period. In solutions containing up to 67 ppm $CO_2$, survival times are shortened by an increase in temperature from 12.5 to 19.5°C.

Seidmore (172) reports on studies of winter kills on six southern Minnesota lakes which lead to the conclusion that the dissolved oxygen level is the best basis for forecasting winter kills. High concentrations of carbon dioxide, hydrogen sulfide, and ammonia are concurrent phenomena of low oxygen conditions and are not the cause of the kills. In connection with a fish kill below a kraft pulping plant in India, field bio-assays were run (15) to determine the toxicity of free chlorine ($Cl_2$) at different DO concentrations. It was found that 0.2 ppm $Cl_2$ killed all the test fish at DO levels of 1.0 to 2.0 ppm but did not kill fish at 5.0 ppm DO. The resistance of several species of fish to low DO concentrations was tested by Downing and Merkens (48) at temperatures of 10°, 16°, and 20°C. Rise in temperature reduced the resistance of all species tested to low DO. Tench were the most resistant to low oxygen and in general trout were the most susceptible.

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## Toxic Wastes

### *Methods*

Bio-assay procedures are now in wide use for the determination of the toxicity of wastes and other materials to fish and other aquatic organisms (185). Work is also under way to develop methods for using the results of short time tests to indicate safe concentration under conditions of continuous exposure. Studies are being made of a great variety of toxicants and the influence of various environmental conditions on their toxicity.

Burdick (25) suggests that the curvature found in logarithmic plots of concentration against time for death in toxicity studies is induced by failure of the effective range to conform to the axes of the paper. Translation may be effected by subtracting the threshold value from concentration and a minimum time from death time. When this is done the curve becomes a straight line and represents a simple inverse proportion. A graphical method is presented by which these corrections may be approximated and an equation for the original curve derived. The value of this procedure lies in the evaluation of the threshold concentration which may be used to establish safe disposal rates for toxic wastes.

Merkens (132) has described an apparatus requiring very little manual attention which can be used to vary independently the temperature, pH, DO, and concentration of toxicants in water supplied to six specially designed aquaria. Halsband (71) developed a method for assessing the toxicity of substances in water through changes in respiratory rates. Fish are kept in a constant flow of water in a dark pipe. Their respiratory movements are measured by a new electrical method, first in normal water and then after the addition of the toxic substance.

As the result of tests carried out in Belgium by LeClerc and Devlaminck (111), the value of bio-assays in assessing water quality is discussed. It is concluded that fish toxicity tests are of use for determining the effect of a given effluent on fish in a river and the dilution or degree of treatment required to prevent fish mortality. A field technique has been developed by Klock (102) whereby the concentration of sodium pentachlorophenate in natural waters can be determined by observing the mortality rate of the common guppy and comparing it with standard mortality curves developed for known concentrations of the material under conditions encountered in the field.

Henderson (76) points out that the toxicity of mixed industrial wastes cannot generally be estimated from chemical composition. It is necessary to conduct bio-assays with the mixed waste using for dilution the water from the receiving stream or water with similar characteristics. Further, a numerical value called the application factor must be developed and applied to the $TL_m$ derived from short time tests to indicate safe concentrations for aquatic life under conditions of continuous exposure. In developing the application factor major consideration is given to relating the test to actual conditions, the test fish to other aquatic life, and to possible effluent fluctuations.

Garrett (61) points out that it is becoming increasingly important to obtain biological information on a waste problem and in many cases this information is as important as chemical and engineering data. Bio-assay data on wastes from a chemical manufacturing plant were used in the design of waste treatment facilities. One-tenth of the 24- or 48-hr $TL_m$ was set as the effluent standard. In another article (62) the same author points out that the most serious toxicity problem facing a manufacturing plant in providing for waste discharges is concerned with the effects on aquatic life. One of the principal reasons for this is that the appearance of dead fish in a receiving stream has long been considered the ultimate evidence of bad industrial practice.

The use and value of bio-assays in meeting toxic industrial waste problems, methods, equipment, supplies, procedures, and costs for carrying on bio-assays, and the use of bio-assay results in meeting specific problems are described by Henderson and Tarzwell (77). Several examples are given of the use of bio-assays by industry in the safe disposal of toxic wastes. Conventional physical and chemical tests of the effluent of a large synthetic fiber plant gave no evidence of serious pollution. Bio-assays showed this effluent to be highly toxic to fish under minimum river flow conditions and also helped to locate the major toxic component. Attention to the elimination of this material in the treatment process restored the aquatic life of the river in a short time.

According to an article by Vinogradov (194) the sanitary authority of the U.S.S.R. is meeting toxic waste problems by limiting the concentration of certain substances which may be discharged. The limit for lead, copper, nickel, cyanide, and chromium is 0.1 ppm, and for other materials is as fol-

lows: picric acid, di- and tri-nitrotoluol, dinitrochlorobenzole, tetranitromethane, 0.5 ppm; mercury, 0.005 ppm; arsenic, 0.05 ppm; carbon disulfide, 1.0 ppm; fluorine, 1.5 ppm; carbon tetrachloride, 5.0 ppm; DDT, 0.2 ppm; dinitronaphthalin, 1.0 ppm; dichlorethane, 2.0 ppm; and chlorine, 0.0 ppm. This approach disregards the quality of the receiving water, synergy and antagonism, wastes already present, and size of the receiving stream, but gives strict and uniform regulations which are easier to enforce.

Tests by Weiss and Botts (203) indicate that the time of response of fish to Sarin decreases relative to decreases in the DO content of the water. Fish used in the studies were fathead minnows, green sunfish, and goldfish. The toxicity to *Gambusia* of 86 compounds which may occur in oil refinery wastes was determined by means of bio-assays and reported by Wallen *et al.* (199). Because the waters of Oklahoma, which were of chief concern, are mostly turbid, bio-assays were conducted in turbid water. The results seem to suggest a protective action of the turbidity. This may account for the fact that some of the results are at variance with those obtained by other workers. For some years bio-assay tests have been carried out in an effort to find a specific toxicant for the larvae of the sea lamprey, *Petromyzon marinus*, in the Great Lakes area. Applegate *et al.* (14) reported on tests that were made with the lamprey, rainbow trout, and the bluegill. Of the 4,436 chemicals so tested, 264 were toxic to only one species and 333 were toxic to only two species. This work has led to specific materials for the control of the lamprey larvae; namely, the nitrophenols.

*Metals*

Extensive experimental studies in Russia (187) of the effects of dilute solutions of toxic substances, discharged into the Kama River, on various types of river bottom animals indicated that 0.01, 0.002, and 0.001 N solutions of $K_2Cr_2O_7$ were lethal in 25, 47, and 67 min, respectively, to *Daphnia pulex*. Similar tests were made with $Pb(NO_3)_2$, methyl violet, and other industrial wastes. Among other harmful industrial wastes are those from dye plants, coke plants, oil refineries, soda works, paint factories, and fertilizer works. In Japan it was found by Koenuma (103) that a $5 \times 10^{-4}$ M sea water solution of uranyl nitrate inhibited the formation of the fertilization membrane in *Urechis* eggs and led to polyspermy. These findings indicate that in determining the effects of toxic materials more than lethal effects should be considered. Experiments by Alderdice and Brett (4) with chum salmon, *Oncorhynchus keta*, 3.9 to 5.8 cm in length in salinities of 17.9 to 18.1 ppt, at temperatures of 14.4 to 15.0°C, and at DO level of 85 per cent of saturation, indicated a 48 hr $TL_m$ value for $As_2O_3$ of 11 ppm.

There is now experimental confirmation, as reported by Shaw and Grushkin (175), of the hypothesis that metallic cations are toxic because they combine with an essential sulfhydryl group or a key enzyme. It is assumed that the affinity of the cations for the sulfhydryl group is a linear function of the insolubility of the corresponding metal sulfide. Metal ions that form the most insoluble sulfides will also be the most toxic. Experiments carried out with distilled water indicate that the metals, listed in their order of toxicity, are as follows: Ag, Hg, Cu, Cd, Pb, Zn, Ni, Co, and Mn. Experiments with fish spawn, young fish, and *Daphnia* (154) showed that zinc plates placed in hard well water did not form poisonous salts but such salts were formed in soft water ponds to produce toxic conditions. Other experimental studies by Cairns and Scheier (29) indicated that temperatures, as well as hardness, influence the toxicity of Zn. In soft water the 96-hr $TL_m$ was 2.86 ppm at 18°C and

1.93 ppm at 30°C. In hard water it was 10.13 ppm at 18°C, and 10.15 ppm at 30°C.

Bio-assays by Corner and Sparrow (41) to determine the effects of various Cu and Hg compounds on *Artemia salina*, *Elminius modestus*, and *Acartia clausi* indicate that the latter two were more sensitive than *Artemia* to all the materials tested. The mercuric compounds were more toxic than Cu to *Artemia*. Mixtures of the two materials gave a synergistic effect. Exposure of *Artemia* to Cu rendered it much more sensitive to subsequent exposure to $HgCl_2$, but not to Cu. The opposite was also true. Additional studies by the same authors (42) demonstrated that the toxicities of primary alkylmercuric chlorides become considerably less when cystine and reduced glutathione are added to the toxic media. In general, a good measure of agreement has been found between the relative lipoid solubilities of both primary and secondary alkylmercuric chlorides and their respective toxicities to *Artemia*.

Many toxic materials are not avoided by fish. Studies by Cairns (28) were made on the effects of periodic low oxygen and it was found that when the DO was lowered to 2 ppm for 2 hr in each 24-hr period the materials under study become considerably more toxic: KCN, about 4 times; naphthenic acid, 2.5 to 3 times; and $ZnCl_2$ about 1/3 more.

Saiki and Mori (165) found that the accumulation of $Zn^{65}$ in the clam, *Meretrix meretrix*, was high in the gill, mantle, viscera, and other soft tissue, but there was very little in the shell. About 40 per cent of the radioactivity was lost in 2 days after removal to normal sea water. With the carp much of the radioactivity was deposited in the gills and kidneys as was the $Zn^{65}$ injected into the muscles. After 48 hr, $Sr^{90}$ injected into the muscles was found largely in the hard tissues; whereas $Cs^{137}$ was chiefly retained in the heart and kidney and found in both soft and hard tissues.

*Phenol*

Experiments in France by Brebion *et al.* (21) with fractions of the black liquor from the sulfate process demonstrated that there was no relation between phenolic concentration and toxicity and that the most toxic fraction was the residue after distillation, which contained no phenols.

*Ammonia*

Bio-assay studies with un-ionized ammonia by Merkens and Downing (133) indicated that the period of survival for all species decreased as the concentration of the toxicant increased; decreasing DO increased toxicity with the greatest effects at the lower concentrations of un-ionized ammonia. Resistance of perch and roach to lack of DO was not significantly affected, but that of rainbow trout was reduced significantly by a small concentration of the un-ionized ammonia.

*Paper Mill Wastes*

Alderdice and Brett (3) exposed sockeye fingerlings, *Oncorhynchus nerka*, to various concentrations of full bleach kraft effluent under experimental conditions simulating those anticipated in the estuary of the Somass River, British Columbia. At 17.8°C in sea water of 20 per cent salinity, the limiting concentration of toxicant below which survival was complete and independent of length of exposure, was 4.8 per cent. However, when DO requirements for respiration and oxidation of the waste were considered, it was necessary to lower the concentration of the waste effluent from 4.8 to 2.5 per cent.

In studies carried on in Japan (95) it was concluded that the harmful effect of paper mill wastes on aquatic organisms is mainly due to active $Cl_2$ in the effluent from the beater, in sediment of the bleaching liquor tank, and in the effluent from the factory.

*Detergents*

In an investigation of detergents by Herbert *et al.* (79) it was found that toxicity was mainly due to alkyl-aryl-sulfonate and that about 3 ppm of this material produces a 50 per cent fish mortality in about 12 weeks. When they are present more DO is required to sustain the fish. It is stated, however, that detergents do not constitute a threat to fishes.

*Other Toxicants*

Aquatic animals can tolerate concentrations of tannery wastes up to 4 per cent when chromates are not present. The toxicity of tannery wastes is attributed by Wlodek (209) to reduction in DO, changes in salt concentration, and changes in acidity. DeWitt (46) reported that latex tubing used in a recirculating experimental apparatus in which the water was not exchanged proved toxic to stonefly nymphs. In jar tests, the tubing caused the death of stoneflies in 72 hr and small Chinook salmon in 24 hr.

Krumholz (104) described a three-year study of fish populations in White Oak Lake which received radioactive and chemical waste-waters from Oak Ridge National Laboratory in which it was shown that fish in the lake grew more slowly and did not live as long as fish in nearby reservoirs of the Tennessee Valley Authority. Radioassay indicated that radioactive materials were selectively concentrated in all tissues of the body. Radioactive Sr and P were found in the hard tissues, and Cs and the rare earths in the soft tissues. The total radiation received by the fish was estimated to be 57 rep per year from external radiation and several times that amount from internal radiation. Fast-swimming carnivorous fish fed $Sr^{89}$ excreted most of it in a few hours. The remaining $Sr^{89}$ was found mostly in the skeleton. Excretion was much slower and retention much higher in a small sluggish herbivore.

Boroughs *et al.* (19) found that about three times as much Sr was found in the muscles of injected tuna as in those receiving the isotope orally, while the gills had only half the activity found in orally fed tuna. The same authors (20) reported that when capsules containing 5.5 $\mu$c of $Y^{91}$ were placed in fishes stomachs the rate of loss of $Y^{91}$ was very high, only 2 per cent of the dose being retained after two days.

*Insecticides*

The widespread use of the new organic insecticides and their increasing significance as water pollutants are indicated in the literature. The use of these materials for area control has resulted in several extensive fish kills and a reduction in the fish food organisms. In a report by Ide (87) the number and volume of aquatic insects emerging from tributaries of the Miramichi River of northern New Brunswick, where forest-covered watersheds had been sprayed from the air with 0.5 lb of DDT per acre, were compared with insects emerging from unsprayed streams. It was found that there were fewer kinds of insects in the sprayed streams, and the greatest reduction occurred in the larger species which are the main food of the young salmon. A sudden complete mortality of landlocked salmon fingerlings in a commercial fish hatchery was believed to be due to aerial spraying with DDT. Bio-assay studies showed that landlocked salmon are more sensitive to DDT than either rainbow or brook trout. Low DO levels increased the toxicity of DDT. Under conditions of oxygen saturation, 0.08 to 0.16 ppm DDT is lethal to landlocked salmon but sublethal for rainbow and brook trout (73). George *et al.* (64) described studies in which two applications of BHC, DDT, and Strobane at the rate of 0.1, 0.2, and 0.3 lb/acre, respectively, were made to the tidal marshes of Bombay Hock National Wildlife Refuge. At this low rate of application no damage of consequence

was observed from the two applications, with the exception of that to the marsh fiddler crab. Bio-assay tests with toxaphene indicated a three-fold increase in the toxicity to bluntnose minnows when the temperature was raised from 50 to 75°F.

In work by Hooper and Grzenda (84) toxaphene was found to be more toxic to the bluntnose minnow than to some of the aquatic invertebrates. In treated lakes many groups of invertebrates were killed but they reappeared while the lake water was still toxic to fish. Detoxification in water proceeded more rapidly when it was exposed to light and where the temperature and DO were high.

As described by Opheim (147) in July 1955, the U. S. Forest Service sprayed 132,856 acres of the upper Yellowstone River drainage with approximately 133,000 lb of DDT for spruce budworm control. First observations of dead or dying fish in the area were made in mid-October 1955. Mortality was extensive but predominantly whitefish were affected. Dead fish were in an emaciated condition and it is believed death was due to reduced food supply. Comparison of sprayed with unsprayed areas revealed a noticeable absence of stoneflies, caddis flies, and mayflies in the treated area. Tarzwell and Henderson (186) reported that bio-assays were made of the runoff water from an experimental plot before and after treatment with dieldrin. It was found that the runoff from the first rain from an area treated with dieldrin at the rate of 5 lb/acre was toxic to fathead minnows in a one in three dilution. Some toxicity to fish was still present in runoff from the third rain after treatment.

Cushing and Olive (43) stated that the application of approximately 0.1 ppm of toxaphene had a marked detrimental effect upon the Tendipedidae population of a northern Colorado lake. Living larvae were absent three days after treatment and repopulation was not complete until nine months later. The Oligochaetes exhibited no adverse effects from the toxaphene. Rotenone had little adverse effect when applied at 1 ppm.

A thorough summary of the pesticides, their use and toxicity to wildlife, has been prepared by Rudd and Genelly (164).

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## Putrescible Wastes

### *Effects of Organic Enrichment*

Ellis and Gowing (49) in a field study of two stream sections, one in its natural state and the other enriched by the sewage from a town of 500 people, showed that trout grew much faster and were in better condition, and the bottom fauna was more abundant in the enriched section. Physical, chemical, and biological surveys of the Sone River in India (138), which receives wastes from kraft pulp mills, a sugar factory, and cement factory, showed that the involved portion of the stream may be divided into five zones according to the degree of pollution. Toxic constituents of the pulp mill were well-diluted even during the low-flow period but the high organic content of the wastes reduced the DO to near zero and changed water quality and bottom conditions for 15 miles, adversely affecting the fish and invertebrate habitat.

Galtsoff (58) reports that the production of oysters in the United States has declined to half its former volume. Domestic and industrial wastes affect the oyster bottoms by (a) direct poisoning of shellfish, (b) smothering of shellfish grounds by sludge, and (c) rendering the water unsuitable for harvesting shellfish because of the high bacteria content. Siltation has covered many beds. Sulfite mill wastes encourage the diatom *Melosira*, which increases to the point where the oysters are smothered under a thick blanket of diatoms. Overfertilization by duck farm wastes produced a similar problem. In Britain, Cole (35) observes that many formerly productive oyster beds have either been abandoned or have declined in value as domestic and industrial pollution has increased. A study by Wood (210) of the process of pollution and self-purification in oysters and mussels indicated that when the water temperature is above 10°C both pollution and cleansing take place rapidly as the quality of the water overlying the bed alters and both types of shellfish may become highly polluted. When the temperature of the water is about 1 to 2°C mussels continue to show this same pattern of pollution and cleansing but oysters may not become polluted.

Van Beneden (192) points out that suspended matter may represent a greater pollution danger than liquid effluents. The deposition of sludge on the stream bottom has many biological effects and is of outstanding importance. Nelson and Edmondson (142) indicate that fertilization can have very marked effects on plankton production and general productivity, transparency, and pH. Investigations of the area around three sewage outfalls in south-

ern California by Stevenson and Grady (178) indicated discoloration of the water and increased plankton growths. Investigation by Uhlmann (191) in Germany of a number of small ponds showed that the addition of sewage increased *Daphnia* populations. Experiments by Bringmann and Kuhn (22) on eutrophication in mixtures of river water and effluents showed that algae titre is affected by numerous factors and can be used as a criterion of the degree of eutrophication of water and mud.

*Indicators of Organic Enrichment*

It was found in French studies by Guelin (70) that the intestines of fishes caught offshore in the Mediterranean were free of entero-bacteria, whereas in those caught in the littoral zone there was an intestinal flora similar to that in man or the warm-blooded animals. Laboratory studies have shown that the investigation of the entero-bacteria and enterophages in fishes can give information as to the pollution of the waters in which the animals live. Hartman (72) reported on bottom samples from Santa Monica Bay, California, which indicated six biological zones, each supporting a characteristic fauna which differs with depth of sea floor, nature of sediments, and distance from the end of outfall sewers. Bottom fauna studies by Reisch (160) in the Los Angeles Harbor area, in the vicinity of waste outfalls, indicated that the area can be divided into five zones on the basis of bottom conditions and bottom organisms. Samples taken in a line away from the waste outfalls indicated that the number of species of bottom organisms increased with distance. *Capitella capitata* was found in the zone around outfalls and appears to occupy a position similar to *Tubifex* in fresh water. In the Los Angeles Bay area the same author (159) observed that dredging provided new and clean bottom areas which were then colonized by benthic organisms. Within a year conditions deteriorated and oil sludges deposited on the bottom. The effects of the removal of contaminated bottom materials and the progress of contamination thereafter were demonstrated by DO, sulfide, odor, organic carbon content of deposits, and the makeup of benthic populations.

Weimann (202) believes that organisms serve as indicators of different degrees of organic enrichment or pollution and that the flora and fauna can give more information than chemical and bacteriological examination. Kabler (92) states that from a bacteriological point of view the coliform group is currently considered the best available indicator for use in the estimation of pollution of waters and in the sanitary evaluation of pure waters of potable quality. Only when the count exceeds a normally expected minimum number of coliform organisms is pollution indicated.

Cooke (38) concludes that fungi which are very common in association with decaying organic matter cannot be used as indicators of pollution because of their ubiquity throughout nature. Pollution tolerances occur but must be evaluated carefully in regard to individual species. A negative approach can be used wherein larger numbers of colonies of small numbers of species can be isolated from samples obtained in the more polluted portions of a single stream.

Studies by Patrick and Hohn (151) indicate that results of river surveys have shown diatoms to be easy to collect and study and good indicators of river conditions. It is believed that similar relationships hold for estuaries, bays, and ship canals as for fresh water rivers. From many studies that have been made and reported by Patrick (150) it is believed that diatoms can be used as a group to indicate the ability of a water to support aquatic life. From variation in the number of species and individuals of each species, curves are developed which when com-

pared may reveal waters adversely affected by pollution, mildly affected, severely affected, or not affected.

In Florida, Beck (18) indicates that the indicator organism program is based on organisms which are indicative of the absence of organic pollution rather than on its presence. Surber (183) concludes that the number of species present and the abundance of individuals appear to be a criterion of pollution in lakes as well as in streams. In enriched areas the following forms were the most abundant: Tubificid worms, *Procladius* midges, *Tendipes plumosus*, and *Tendipes tentans*. Under conditions of severe pollution with organic wastes only the Tubificidae were able to survive. Palmer (148) found that the genera of algae occurring most frequently in enriched waters are *Oscillatoria*, *Euglena*, *Navicula*, *Chlorella*, and *Chlamydomonas*. The five most abundant species are *Nitzschia palea*, *Oscillatoria limosa*, *O. tenuis*, and *Arthrospira jenneri*.

In work reported by Lackey (105) immediate sewage pollution of a stream, resulting in oxygen depletion, tends to eliminate all but a few species of anaerobic ciliates and colorless flagellates. Certain species of algae and protozoa are readily associated with sewage wastes but investigators should distinguish between "characteristic of" and "indicative of" organic enrichment.

Ingram (89) found that certain mollusks, as the Unionidae, are not associated with near septic water resulting from organic enrichment. Such forms have an index value in that their presence typically indicates good DO and attendant physical and chemical conditions associated with clean water, and they may be called index organisms of clean water. Studies in the River Moravice in Czechoslovakia by Libosvarsky (116) indicated that several species of Trichoptera were indicative of pure water conditions. Among these were *Polycentropus flavomaculatus*, *Notidobia ciliaris*, *Rhyacophila septentrionis*, *Glossosoma boltoni*, and several others.

Gaufin (63) makes a number of statements relative to the use of aquatic insects as pollution indicators.

In order to utilize macro-invertebrates as indicators of environmental conditions in streams it is essential to have a knowledge of the composition of the population and the abundance of the different organisms under the various environmental conditions which prevail in clean and organically enriched waters. Clean waters are usually characterized by a great variety of invertebrates, consisting of herbivores, carnivores, and omnivores, as well as lung, tracheal tube, and gill breathers. In general, a population containing numerous gill-breathing forms such as mayflies, stoneflies, and caddis flies, is indicative of clean water, and their absence denotes a superabundance of organic materials and/or low DO. By contrast, associations engaged in the utilization of excess organic materials are characterized by few species but large numbers of individuals. The macro-invertebrates most characteristic of septic zones are those which can exist under conditions of low oxygen or have adaptations for breathing atmospheric oxygen.

Doudoroff and Warren (47) reach several conclusions in regard to biological indices of pollution. The terms pollution and biological indicators are often loosely used. Biological indicators are generally indicators of organic enrichment. Pollution means damage to a beneficial use. Changes in an aquatic fauna do not necessarily mean there has been damage. It is believed that a more definite relationship must be shown between changes in the biota and damage to beneficial use before certain organisms can be referred to as pollution indicators. A study of the fish population and the fish catch gives the best information on how wastes are affecting sport or commercial fishing.

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## MICROBIOLOGY

An explosive epidemic (195) of infectious hepatitis in Delhi, India, was attributed to municipal drinking water, and showed that the virus was not inactivated by the treatment methods used. This incident indicated that contamination of the drinking water supplies by sewage should be avoided, if at all possible.

Richter (162) has reported the presence of at least 8 species of *Salmonella* present at various times in channel water in Buxtehude Rasch, Germany. He noted the increasing occurrence of the *Salmonella* group in western Europe as a result of intercontinental travel. Stoll (179) reviewed the legal provisions of the German Democratic Republic in an attempt to prevent human infection through polluted waters from slaughter houses. The conditions under which *Salmonella* can live and grow in water, such as presence of protein materials, effect of salinity, influence of movement, and stagnation were discussed by Steiniger (177). He concluded that the degree of pollution, oxygen demand, and coli content are not suitable methods of determining the presence of infectious agents; more *Salmonella* may be present in apparently clean water than in a polluted water. Greenberg, Wickenden, and Lee (69) have successfully identified an *S. typhi* carrier in a town of 2,200 by application of the swab procedure developed by Moore, in which gauze swabs were suspended in sewage at various points through the sewer system and followed back through house connections into the toilets. A new procedure for the more rapid isolation of *Salmonella* from polluted water was described by Kenner, Rockwood, and Kabler (99). The technique combined the use of a selective medium, selenite brilliant green, with membrane filter culture.

Gol'dfarb (67) demonstrated dysentery bacilli in low concentration in water by the phage titre increase reaction. In experimentally infected well water, bacteria were detected in lower concentration and over longer periods of time than in tap or river water. Kenner and Kabler (98) isolated five strains of *Mimeae* from Ohio River water. All previous isolations of these organisms have been made directly from specimens of human origin.

Greenberg and Kupka (68) have reviewed the subject of transmission of tuberculosis by waste water. Hospitals treating tuberculosis patients, as well as dairies and slaughter houses handling tubercular animals, may be expected to discharge tubercle bacilli in their wastes. Conventional sewage treatment is inadequate to significantly reduce the number of tubercle bacilli in the sewage. In order to provide adequate disinfection, complete treatment plus chlorination with 20 ppm for at least 2-hr contact time is necessary. Cooke and Kabler (40) and Cooke and Busch (39) found sewage-polluted waters to be rich in certain strains of "plant disease fungi" and cellulose-decomposing fungi which have become acclimated to living in aqueous habitats, and which were able to use dissolved oxygen in competition with other sewage organisms for reduction of organic materials. During the treatment of sewage and wastes these fungi were active in purifying sewage in which they were living.

Dauer and Sylvester (44) in their summary included nine water-borne outbreaks in which 1,719 persons were affected. Two large and two small outbreaks were from contaminated public water supplies; one of 800 cases was due to *Shigella flexneri*. One outbreak of typhoid fever (27 cases) was attributed to contaminated well water. One outbreak of infectious hepatitis of 276 cases was considered waterborne and *E. coli* was isolated from the supply.

Hendriksen (78) has extended his studies on coliform tests of water carried out in mannitol broth at 30°C followed by subcultures in lactose broth at 39°C. The rate of coliform detection was higher by the new method and seemed to give more reliable results than tests in lactose broth at 37°C. Karakasevic (94) made a comparative study of culture media for the enumeration of coliform bacteria, and recommended that the technique now in use in Yugoslavia be replaced by the standard procedure used in the U. S. In his study of the effect of storage temperature on the survival of coliform organisms in water, McCarthy (127) found that water samples with relatively low coliform densities (23 or less) which had been in shipment up to 24 hr at any reasonable temperature yielded results which statistically correlated very well with the degree of pollution existing at the sampling point at the time of collection. Samples with higher initial coliform densities (230 or more) were more likely to exhibit decreases in coliform content during 24-hr storage. Njoku-Obi and Skinner (144) consistently obtained lower counts of coliforms and *Escherichia* species in boric acid lactose broth at 43°C than when standard lactose broth was used at 35°C. They concluded that boric acid lactose broth cannot be depended upon to detect fecal coliforms, although they did not clearly define their criteria for differentiating *Escherichia, Aerobacter,* and intermediate forms.

Sullivan, Bartley, and Slanetz (182) reported that the enterococci occur in the feces of man and certain animals and in polluted water or sewage in as great or even greater numbers than do the coliform bacteria, and that in some instances it may be possible to distinguish between human and animal contamination of water, based on the types of enterococci present in the samples. In the examination of 1,000 water samples in Argentina, Leiguarda *et al.* (113) demonstrated contamination in 332, 83.1 per cent contained coliforms, and 45.8 per cent contained streptococci. Because 16.9 per cent of the contaminated samples contained streptococci only, they considered the possibility of adding tests for streptococci to the other methods used in the bacteriological examination of water.

Reitler and Seligmann (161) showed that *Pseudomonas aeruginosa* and *E. coli* can coexist in pure water, but in mixed cultures in peptone water *Ps. aeruginosa* can inhibit *E. coli*. Water supplies containing many *Ps. aeruginosa* but few or no *coli-aerogenes* bacteria were found to be relatively common in northern Israel, and in view of *Ps. aeruginosa's* fecal origin and its potential pathogenicity, it was concluded that this organism should be considered as well as the *coli-aerogenes* bacteria in assessing the suitability of water for drinking purposes. Due to the high concentration of cytochrome oxidase within the cells of *Ps. aeruginosa* a practical differential test has been developed by Gaby and Hadley (57), based on the formation of indophenol blue from the oxidation of P-aminodimethylaniline oxalate in the presence of alpha naphthol. This test suggests the possibility of a procedure for the selective enumeration of *Pseudomonas* in polluted water.

Collin and Kipling (36) have devised a new technique for the enumeration of water-borne bacteria by a "direct count method." Results by the direct count were from 6 times to 11,000 times greater than by the colony count. Fournelle (54) described a procedure for determining the potability

of water supplies in the field, which is said to be adaptable to special areas for removal from a laboratory. Fournelle and Page (55) found the dye uranin and *Streptococcus zymogenes* to be satisfactory indicator agents to determine the direction and rate of travel through ground waters. Robson (163) added *Serratia indica* to sewage to determine the distribution of effluent material discharged into the sea.

Willis (206) showed that black colonies, 3 mm or more in diameter, which developed on Wilson and Blair's medium inoculated with untreated water from a city's supply, signified the presence of *Clostridia*, usually *Cl. welchii*. The same author (205) also found anaerobic bacilli in the sand from the filter-beds of a city water supply, and thought it probable that these organisms were being added to the water as it passed through because anaerobes were present in the treated water. It was pointed out that the anaerobe test on treated waters was useful in assessing filter efficiency.

Friberg and Hammarstrom (56) studied free available chlorine effects on bacteria and bacteria viruses. At pH 7.2 and temperature of 6°C, exposure for 1 min to a concentration of 0.025 to 0.05 mg/l chlorine effected a thousandfold reduction of typhoid bacilli, *S. sonnei*, and coliform bacteria, but concentrations of 0.10 to 0.15 mg/l chlorine were necessary to effect the same reduction in numbers of *Sal. typhimurium*, *Strep. faecalis*, and *Staph. aureus*. The coliform, *sonnei*, and *typhimurium* phages were reduced a thousandfold by concentrations of 0.04 to 0.07 mg/l free chlorine. Kelly and Sanderson (97) pointed out that chlorine residuals found to be sufficient for bacterial disinfection were not similarly effective as viral disinfectants, and that inactivation of polio virus by chlorine may follow a course not strictly linear. Watkins, Hays, and Elliker (201) made a comparison under laboratory conditions of the relative effectiveness of representative hypochlorite, quaternary, and iodophor germicides in the destruction of *Strep. cremoris* phage. The results suggested that an active hypochlorite preparation should provide the most effective sanitizing procedure for control of bacteriophage in dairy plants.

Fetner and Ingols (52) determined the lethal concentration of ozone for *E. coli* suspensions at 1°C to be 0.4 to 0.5 mg/l. Ladendorf and Ladendorf (106) have made similar observations on the efficiency of chlorine dioxide for disinfecting water.

Lowe and Lindsten (120) have summarized the removal of CBR contaminants from water. Lewisite and nitrogen mustard can be effectively removed by treatment with activated carbon followed by thorough coagulation and filtration; GA and GB were reduced by treatment with soda ash plus coagulation and filtration. *Sal. typhi*, *Coxiella burnette*, and *Botulinum toxin* were removed by coagulation, filtration, and chlorination to 20-min residuals of 0.35 to 0.75 ppm.

Taylor in England (188), Schiavone and Passerini in Argentina (168), Adams in Pennsylvania (1), and Gohar and Eissa in Germany (66) have compared the membrane filter technique with other acceptable methods in the bacteriological examination of water. They have pointed out certain advantages of the method and have also listed limitations. These advantages and limitations have been discussed by Clark, Kabler, and Geldreich (32). Felsenfeld and Rokkaku (51) have adapted the membrane filter technique to the recovery of *Vibrio comma* from water supplies and Papavassilion and Wegner (149) have used the technique for the detection of sulfite-reducing clostridia (*Cl. perfringens*) in water and other liquids.

Levin, Harrison, and Hess (115) have published further observations on the use of radioactive culture media in the enumeration of coliform organisms in water. They found that pH exerts a pronounced biological and chemical ef-

fect on the test. When the broth is alkaline, much of the carbon dioxide remains in solution in the form of the bicarbonate ion. The nonmetabolic evolution of $C^{14}O_2$ from the sterile 1-$C^{14}$ lactose is the chief immediate problem demanding attention in the development of the test.

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## CHEMISTRY

Heukelekian (80) assembled a notable symposium in which it was sought to present a review of the basic microbiological processes related to purification of polluted waters. While many of the papers may be noted elsewhere, the assembled symposium is deserving of attention. It includes discussions by Wyss on "Microbial Adaptation"; Weindling on "Microbial Associations and Antagonisms"; Nickerson on "Transformations of Carbon Compounds"; Delwicke on "Biological Transformations of Nitrogen Compounds"; Starkey on "Transformations of Sulfur by Microorganisms"; Barker on "Biological Formations of Methane"; Davis on "Microbial Decomposition of Hydrocarbons"; and Krauss on "Photosynthesis in the Algae." Each article is discussed by one or more authorities.

The direct chemical characterization of organic water pollutants has found continued application and study. Middleton and Rosen (135) review techniques and discuss trends in organic industrial pollution which make specific chemical characterization of pollution a matter of growing importance. Holluta and co-workers (82) (83) have also presented the details of techniques generally aimed at the recovery and characterization of organic materials in surface water and water taken from infiltration galleries.

Sawyer *et al.* (166) reported on the inter-relationship of rates of biological assimilation and chemical structure of synthetic detergent materials. An additional report considering the effect of commercial synthetic detergent ingredients on water and waste quality was presented by Sawyer and Ryckman (167).

Hexadecanol (cetyl alcohol) has been investigated as a water pollutant because of interest in the material as a possible suppressor of evaporation. Laycock (107) commented on the effect of the material on aquatic life. Ludzack and Ettinger (121) report laboratory studies of the biological destruction of hexadecanol and point out that the material undergoes biological destruction under laboratory conditions which simulate proposed use conditions.

Other studies of the biological stability of various materials appeared. Hatfield (74) studied the biological stability of 23 compounds produced by petrochemical processes, using activated

sludge cultures acclimated to the chemical for periods of a month. Ludzack and Kinkead (123) made laboratory studies of the oxidation of hydrocarbons derived from motor oil by microorganisms. They also presented analytical evidence of the formation of intermediate oxidation products.

Mills and Stack (136) emphasized the importance of using acclimated seeds when attempting to estimate the BOD load caused by an industrial waste.

In an interesting application, Christenson *et al.* (31) proposed the use of activated sludge using nitrate ion as an oxidant source and methyl alcohol as organic feed in a system where removal of nitrate from a waste was sought.

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## OXYGEN SAG AND STREAM SELF-PURIFICATION

In the third of a series of reports on comprehensive studies of the character and stream self-purification characteristics of Wisconsin rivers, Lueck *et al.* (124) have presented analysis by several devices of the stream self-purification capacities of the Fox River and other rivers in Wisconsin. They have suggested that the self-purification capacity of streams may be compared on the basis of pounds per day of ultimate BOD satisfied per 1,000 cfs per mile, or on the basis of the time required to oxidize 90 per cent of the ultimate BOD taken together with the deoxygenation velocity constant $k_1$, or on the basis of pounds per day of 5-day BOD per cfs per ppm of DO removed. The capacity of the Lower Fox River at various seasons and in several reaches is compared on the above bases.

On the basis of the third of the above noted units for comparison, namely, pounds of 5-day BOD per day per cfs per ppm of DO removed, the authors conclude that "at low temperatures, when the stream purification proceeds at a slower rate, considerably higher loadings can be supplied to the stream without adversely affecting downstream conditions." And at a later point "it is evident from previous discussion that the lower the purification rate, or $k_1$ factor, the greater may be the load applied to the stream. Any factor such as limited biological activity at lower temperatures or characteristics of the waste to be oxidized which tend to decrease purification rate, will improve purification capacity and make possible the satisfaction of higher loadings."

This concept is rather unusual in that it might imply, for example, that unlimited loads could be placed upon a stream in the event $k_1$ were reduced to zero—by the presence of sufficient amounts of toxic materials, for example. The 5-day BOD is, of course, affected by the course of reaction, or $k_1$, while the ultimate BOD, at least in principle, should not be thus affected. It would be interesting to compare the stated stream self-purification capacities on the basis of ultimate rather than 5-day BOD. Conceptually, if the entire river is considered rather than a restricted reach, the entire pollution load introduced at any point must eventually be satisfied, and the critical point of the oxygen sag curve may or may not occur within this restricted reach, depending upon the specific circumstances involved.

The above paper also discusses the implications of the effects on self-purification capacity of large concentrations of algae.

Mills and Stack (136) have presented a discussion of the effects of acclimation of seed on the course of the BOD reaction in the case of four pure petrochemicals. The 5-day BOD's of the petrochemicals are compared using both unacclimated and acclimated seeds. The organic chemicals used were acrylonitrile, ethylene glycol, carbitol, and acetone. Only the acetone yielded classical BOD behavior without acclimation of the seed. In the other cases, the use of acclimated seed resulted in higher BOD values, more closely approximating the oxygen demands actually exerted in a stream. The authors suggest that, to evaluate the effects of other organic chemicals on stream self-purification capacity, the ultimate BOD should be determined by the use of acclimated seed organisms.

That the potential pollutional effects of organic materials are a function not only of their BOD as usually measured, but also of their persistence and relatively slow oxidation, has been indicated by Ettinger (50). It is indicated in this paper that the theoretical oxygen demand may be distributed at any time as: material oxidized to carbon dioxide, unoxidized readily available food, cell material, and unoxidized exotic food. The actual distribution among these four phases will, of course, be dependent upon the characteristics of the material involved. Selected examples are taken from the literature to demonstrate the effect of acclimation of seeds on organic materials previously looked upon as essentially unoxidizable.

Nickerson (143) has presented metabolic maps of various hydrocarbons, oxygenated compounds, and amino acids as a basis for the understanding of sewage treatment and stream self-purification mechanisms. LeClerc *et al.* (108) have provided an example of the determination of self-purification capacity of a river for the purpose of obtaining water of sufficient purity for the food industry. Pillai *et al.* (153) present an intensive review of the literature on the subject of stream self-purification capacity, together with information regarding self-purification of untreated sewage from Bangalore, India, in a series of open channels. Muller (139) also presents a general review of the factors involved in stream self-purification, notes the inadequacy of even complete biological treatment in densely populated regions, and discusses possible methods of increasing the stream self-purification capacity.

Rand (156) has presented a critical review of the available literature on theoretical aspects of the reaeration factor. In doing so, he has traced the development of theoretical concepts and has correlated these concepts on this subject from their beginnings through the most recent work, including that of O'Connor and Dobbins (146). It is recognized that the work of O'Connor and Dobbins makes possible for the first time predictions of $k_2$, independent of observed data. Rand indicates that the effects of turbulence on the reaeration velocity constant are only now beginning to be understood, and that much further work remains on this phase of the problem The evidence that he has accumulated indicates that the effects of temperature on the reaeration constant are adequately known, but that the effects of various pollutants including ordinary sewage, as well as detergents, insofar as such pollutants affect reaeration, are not well known as yet. In another discussion on this subject Rand (157) presents the results of some of his own experiments on reaeration. Upon examination of various factors which might affect the reaeration rate, he indicates that the BOD correlates best with the observed reaeration rates. Both quiescent and agitated systems were investigated with the same relative effects observed.

Gameson (60) has presented the results of a study of reaeration occurring as the result of water passing over weirs in rivers. He reports that the oxygen content of the water may be increased as much as 50 per cent of saturation, and an empirical equation

to represent these effects is presented. The effects of various types of weirs are discussed. Wagner (197) describes the use of turbines of water power works for the purpose of oxygenating canalized streams. He discusses experiments carried out on the River Brenz, the air requirements, and the effects of various design features of the turbines.

The subject of estuarine pollution is receiving considerably more attention in the recent literature. Kaplovsky (93) has described his investigations of pollution of the Delaware River, using the "same-slack" sampling technique. The "same-slack" method consists of taking from one to three surface water samples in the ship channel at each sampling station just at the time that the tide begins to turn. In other terms, a sampling run is made in which the samples are collected at all stations at the slack of the same tide. That such surface samples are representative of the ship channel water is demonstrated. Kaplovsky concluded that this method of sampling provided results more valid than those obtained by cross-sectional sampling. His data indicate that the "same-slack" method eliminates much of the effect of tidal periods and the results are therefore more easily interpretable. He also states that his studies of the Lower Delaware River indicate no appreciable deviation from the usual picture of self-purification of inland streams; the data regarding the nitrogen balance is especially appropriate in this regard.

Burt and Marriage (27) have presented a theoretical analysis of the distribution of pollution in the Yaquina River in Oregon on the basis of Stommel's (180) equations. The study involved wastes from a proposed pulp mill on the Yaquina River, and five possible outfall locations were investigated analytically. The computations indicated that the pollution concentration near any outfall, as well as the concentration upstream from the outfall, would decrease rapidly as the outfall was moved toward the ocean. However, concentrations at any given point downstream from two or more outfalls were found to be essentially independent of the position of the outfalls. Following these analytical studies, it was decided to pump the pulp-mill waste directly to the ocean and to thereby avoid significant pollution of the Yaquina River.

An analysis of factors affecting the oxygen balance in the River Thames estuary has been presented by Gameson and Preddy (59). The data include dissolved oxygen observations in the estuary over a period of several years. The various sources of pollution have been considered and a theory of mixing outlined, on the basis of which the distribution of oxidizable material from different groupings of waste discharges has been computed. The oxygen balance of the entire estuary was then examined and an average rate of solution of oxygen from the atmosphere estimated. The oxygen balance having been thus estimated, the theory has been checked against a variety of observed conditions in the estuary and agreement of observed and computed data obtained. On this basis, it was then possible to predict oxygen changes most likely to occur as the result of various alterations of pollution loads and other controlling factors.

Ingram (90) has presented a general review of the factors which affect estuarial capacity for receiving wastes. The factors considered include tidal displacement, fresh-water flow, tidal flow, wave action, density currents, vertical and horizontal countercurrents, stratification, and diurnal and nonperiodic wind effects. Combinations and complications of these factors are also discussed. Mann (130) has also presented a discussion of the general hydrologic conditions in a tidal river and illustrated the principles involved by the example of behavior of sewage from the City of Hamburg discharged into the River Elbe. The self-purification

capacity of the tidal stream and effects of polluted tributaries are discussed.

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## STREAM STUDIES AND SURVEYS

Water resource development and conservation with associated water pollution control continues to be of prime importance. Many stream studies, however, fail to reach formal publication and, therefore, are not reviewed. It may be noted this year that several studies of European waters have been reported.

Tsivoglou, Harwood, and Ingram (189) emphasize the importance of stream surveys for adequate control of radioactive liquid waste discharges associated with the rapidly developing private use of radioactive materials. Excessive radioactive wastes from nuclear reactors, uranium mills, and radioisotope research laboratories will interfere with other legitimate stream uses. There is no stream self-purification capacity for radioactive wastes, as there is for ordinary organic pollutants. Control is based on three types of stream samples—water, aquatic biota, and bottom deposits.

A survey was reported by Schneller (171) of a 25-mile stretch of Salt Creek, Ind., to examine the physical and chemical characteristics of the water during the black-water period which persists during leaf-fall, and to compare this condition with that during the remainder of the year. The dissolved oxygen content was shown to decline to a minimum of 0.5 ppm during the leaf-fall when free carbon dioxide was as high as 20 ppm; during the remainder of the year the dissolved oxygen and free carbon dioxide ranged from 5 to 12 ppm and 5 to 15 ppm, respectively. The effect of extreme conditions on fish life is discussed; no serious fish mortalities normally occur. Wiley *et al.* (204) describe the combined chemical, physical, and biological studies on the Lower Fox River, Wis., during 1955–56 through the cooperative efforts of state and industry to determine sources of pollution and the self-purification capacity of the stream. It was found that combined artificial and natural pollutants cause critical dissolved oxygen conditions below major sources of wastes, especially during hot weather. It was further concluded that detailed study of algae problems will be required to assess more accurately the amount of organic matter derived from this source, since it appeared that algae contributes a substantial portion of organic load during warm weather. Scott *et al.* (173) discuss the organization of cooperative state-industry studies in Wisconsin. The cooperative approach permits assembly of much more complete data covering more of the variable factors than would otherwise be available to either industry or government acting alone. Chemical, physical, and biological characteristics

of a 30-mile stretch of the Ottawa River below an oil refinery near Lima, Ohio, was presented by Ludzack, Ingram, and Ettinger (122). Evidence indicates that oil was not biologically assimilated but stored as oily sludge on the river bottom and flushed by periodic river rises. Such accumulated sludges are believed to be responsible for extreme impairment of water quality which sometimes occurs when a river is flushed out following a long period of low flow.

The effects of polluted waters of the Flon on Lake Geneva at Vidy were studied by Monod (137). It was concluded that the chemical composition of the lake water was not altered by the Flon but that turbidity and the quantity of micro-organisms were increased greatly. Noisette (145) conducted surveys on a continuing basis of the mineral content of the rivers in France. The source of minerals was geological, urban and rural sewage, and industrial wastes. The conclusions were that the sources of salts are constant, variation in mineral content of the rivers depending on rainfall and flow. The degree of variation requires precaution by industrial users; geologic factors acting alone can cause high mineralization.

LeClerc, Beaujean, and Heuse, in Belgium (110), studied the pollution and self-purification of the Geer River. They indicate that the principal observations guiding such a study should be based on temperature, time, and turbulence. Particular attention should be paid to gradient, flow, and temperature. LeClerc and Beeckmans (109) describe a series of studies on the Sambre River. Data were gathered on flow, temperature, pH, settleable and suspended solids, dissolved oxygen, 5-day BOD, sulfates, iron, chlorine, and toxicity. LeStrat (114) observes that difficulties in sewage treatment attributed in the United States to detergents have not been experienced in France because laundry water, except in a few large cities, is dispersed to the ground via gutters. As a check on detergents, surface tension determinations are made constantly on the Seine, Marne, and Oise Rivers, and on the Chicky interceptor sewer. While the surface tension value for pure water is 74 to 75 dynes, the rivers run to 70 dynes and the sewer is below 65, sometimes down to 58 dynes.

An article based on the work of Kalweit and Brandt (10) indicates that hardly a river in central Germany reaches a scale of water quality satisfactory for bathing purposes; ground water is being utilized to a greater extent by industry and municipalities due to this condition. Further, it is shown that damage to fisheries on the streams of the German Republic can be caused by removal of oxygen, sewage fungus, presence of metal salts from mining and metal industries, sand, clay, kaolin, coal dust, and cyanide and phenol from chemical industries. Fijiwara *et al.* (53) state that the river Yukawa in Japan contains sulfuric acid derived from sulfur deposits in the Yatsugatake volcanoes districts. The acid is considerably neutralized when the Yukawa River joins the Chihuma, which is used for irrigation and fishing. If the sulfur deposits are mined, it is believed that the increased concentration of acid will damage the use of water.

A summary (7) discusses an investigation, including a model study, which considered disposal of up to 500,000 tons per year of power station ash by cooling water conveyance for disposal by sea; barging to sea was the alternate. Eighty per cent of the ash would be borne away to sea in the cooling water stream and in calm weather be deposited beyond the outfall. When waves are 2 ft high and upwards, this deposit would be broken up and moved out to sea. Experiments in the wave channel pointed to the material being distributed at depths as great as 40 fathoms and probably more, with likely dispersal over a wide area of the North Sea. Shapiro (174) reported on pollution survey sampling of New York har-

bor. The first problem dealt with the extent New York harbor and adjacent waters were actually polluted and the second problem was concerned with the tidal and current distribution of the polluting load. Extensive pollutional and hydraulic surveys were necessary to ascertain details of the problem and background for corrective measures.

The good and bad features resulting downstream from water storage for hydraulic power generation is discussed by Ingols (88). On the good side, water below a dam contains less sediment, color, bacteria, and has a lower temperature. The bad features, oftentimes not fully appreciated, are that directly below the dam, water may be devoid of oxygen during the summer when water quality is critical, and may contain manganese or sulfide. Furthermore, flow pattern of power generation may permit slime development on the bottom during low flow and scouring off of slime during high flow; wastes may be stored in tributaries during high river stages and discharged to the river during falling river stages, and a city may discharge its heaviest sewage load during minimum river stage if located 12- or 36-hr flow time downstream from the dam.

## STREAM STANDARDS

Vinogradov (194) reports that the Sanitary Authority of the U.S.S.R. regulates the concentrations of certain substances in waste waters discharged to streams. These include:

| Substance | Conc (mg/l) |
|---|---|
| Lead, copper, nickel, cyanide, chromium | 0.1 |
| Picric acid, di- and tri-nitrotoluol, dinitrochlorobenzole, tetranitromethane | 0.5 |
| Mercury | 0.005 |
| Arsenic | 0.05 |
| Fluorine | 1.5 |
| Carbon disulfide, dinitronaphthalin | 1.0 |
| Carbon tetrachloride | 5.0 |
| Dichloroethane | 2.0 |
| DDT | 0.2 |
| Chlorine | 0.0 |

In Austria, Liepolt (118) concludes that the primary importance of hygienic considerations justifies the general aim of restoring all Austrian surface waters to their natural condition. He suggests that the minimum standard should be the maintenance of beta mesosaprobic conditions at all times. This biological classification describes the zone of stream recovery, following severe pollution, in which mineralization is approached, blue-green algae, diatoms, and varied animal forms occur, and dissolved oxygen nears saturation.

The Ohio River Valley Water Sanitation Commission staff (6) has proposed a plan for controlling chloride pollution of the river. The average monthly chloride concentration on the main river should not exceed 125 ppm, based on the most probable minimum monthly-average 10-year flow, and the maximum concentration should never exceed 250 ppm. The Commission's primary concern in selecting chloride limits was prevention of corrosion of metal structures rather than protection of health. The low limit needed to prevent corrosion assures chloride concentrations below those acceptable in public water supplies. Alternate schemes for computing allowable discharges of chloride wastes from individual sources are described.

## EFFECTS ON WATER SUPPLIES

Kazuaki (96) attributes an outbreak of acute intestinal disease to contamination of a water supply by wastes from a sweet potato starch factory.

Zimmerman (211) reports on an incident of contamination of the Trier (Germany) water supply due to explosion of a kerosene tank which released kerosene to a tributary of the Moselle River above the town. He also discusses the problems of both surface and underground pollution by motor fuels and precautions in choosing sites and constructing storage tanks for such fuels. The California State Water Pol-

lution Control Board (11) has published a report on an extensive literature survey on the effects of oily substances on beneficial uses of water. Garrett (62) discusses the problem of possible toxic effects of various chemical pollutants in industrial wastes.

A report on the continuing struggle to protect the London (England) water supply against pollution was made (9). The problem of protecting water supplies against radioactive contamination resulting from nuclear reactor operations was discussed (13).

## ABATEMENT AND CONTROL

The completion of the last link in the $80 million sewage collection and treatment system in Philadelphia is reported on by Baxter (16). Some 66 miles of collecting and intercepting sewers plus three sewage treatment plants have been financed by sewer service charges since 1946. Plans are under way between Philadelphia and neighboring communities to bring sewage from outlying areas to the Philadelphia plants. When these arrangements are completed, practically all raw sewage will have been eliminated from the Schuylkill and Delaware Rivers in the Philadelphia area.

Spies (176) reports on the progress in stream pollution control in Oregon. Since the initiation of the state program in 1938 an estimated $50 million has been expended by municipalities, industries, and others for pollution abatement. During this period the state's population has increased more than 50 per cent; however, the population equivalent of municipal sewage discharged without treatment has decreased from 450,000 in 1938 to 60,000 in 1956. In 1938, less than 1 per cent of the industrial wastes was being treated, while in 1956, over 78 per cent received treatment, despite a 67 per cent increase in population equivalent of industrial wastes during this period. It is pointed out that much additional work is required, however, to protect Oregon's waters. It is estimated that 100 communities require new or improved facilities which will cost at least as much as has been spent since the inauguration of the program, and several existing industries will likewise require new or improved treatment facilities.

Cleary (33) in reviewing the progress being made to clean up the Ohio River points out that when the Ohio River Valley Water Sanitation Commission was established in 1948 less than one per cent of the population on the Ohio River provided treatment. In 1957 facilities were in operation or under construction to serve 86 per cent of the population. Good progress is also being made by the industries as evidenced by the fact that more than two-thirds of those plants discharging effluents into the streams of the Valley now comply with Commission minimum requirements for pollution control. The necessity for much more work to be done is seen, however.

McCallum (126) reports on the first year of operation of the Construction Grants program under Public Law 660. This section of the Federal Water Pollution Control Act authorizing construction grants has been the subject of much controversy as to whether or not it would stimulate or retard sewage treatment works construction. Because of the time required for setting up procedures for the administrative grants program no grants could be offered until December of 1956. Reports from state water pollution control agencies as well as contract awards data indicate that the construction picture looks encouraging despite the advent of factors tending to retard construction, the principal one of which has been the "tight" money market.

The Engineering News-Record (112), in evaluating the first year's operation of the Construction Grants program, cites data indicating that Federal grants have stimulated sewage treatment construction.

The restoration of an important water use as a result of effective pollution abatement is reported in the case of the blue point oyster industry (12) in Moriches Inlet and Great South Bay on Long Island. Pollution from Long Island duck farms had practically wiped out the oyster industry. Abatement proceedings initiated by the state in 1951 together with a flush-out of Moriches Inlet by the 1953 hurricane have combined to restore this area to favorable environment for the blue point oyster.

Hoak (81) discusses a rational program for stream pollution control. He feels there is no direct evidence that stream pollution is a significant health factor and calls upon state water pollution control agencies to apply the principle that treatment should be provided only to the extent that it will adequately protect downstream uses of the receiving water. He cites the need for the establishment of criteria to better define the effects of pollution on various water uses and points out that the single most important factor in pollution abatement is education; as the benefits of the abatement program are properly explained, funds necessary to finance construction in order to maintain these benefits will be forthcoming.

Wisdom (208) presents a comprehensive review of English water pollution law and Lovett (119) points out that the enactment of legislation alone does not insure abatement of pollution. A realistic approach and proper appreciation of the need for a policy of true conservation of water resources is essential.

The pollution of surface waters in 18 European countries is discussed by Key (100). This summary supplies information on population, industries, water quality, legal and administrative control measures, waste treatment facilities, sewage, and special national and international problems for these several countries. The story of gross pollution in Europe is largely the story of industrial areas. However, serious problems resulting from bacterial pollution from domestic sewage are prevalent in small localized areas. The author observes that the pollution problem may be expected to increase as the general standard of living rises and the final and permanent solution cannot now be foreseen. The most difficult pollution control problems appear to be associated with the paper and allied industries. Other important industries are sugar beet, dairy products, gas and coke, textiles, mining, and metallurgical.

In discussing pollution prevention philosophies and conflicts of interest the author notes that several European countries have laws a century or more old designed to protect fish from the effects of pollution. It is pointed out that this may be understandable since the disappearance of fish is often the most obvious effect of pollution and needs no scientific test to establish the fact. The observation is made, however, that over-stressing of this point may be in conflict with other uses that may be more beneficial to mankind. The point is made that often unrealistic laws have not prevented pollution. All of these facts point up the need for better definition of the aims of pollution prevention in European countries. In many instances mistakes of ignorance were made which now can be rectified only at an enormous expense. Had present developments been foreseen, definite approaches to protecting the water resources would no doubt have been applied. Newly developing countries should benefit from these unfortunate past experiences.

Tsivoglou and Towne (190) call attention to the need for state water pollution control agencies to assume increased responsibilities in the control of radioactive discharges to surface waters. The desirability of basin-wide planning in establishing control measures is emphasized.

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## CLEAN STREAMS

The Water Resources Council, consisting of a number of organizations interested in stream improvement, on June 11 presented its Clean Streams Award to the City of Philadelphia for marked improvements in the Delaware and Schuylkill Rivers. Secretary of Health, Education, and Welfare, Arthur S. Flemming, made the award to Mayor Richardson Dilworth.

Colonel Willard F. Rockwell, Pittsburgh, Pa., has been elected Chairman of the Water Resources Council for the balance of 1958.

COME TO DETROIT
OCT. 6–9

# Sewage Works

## THE BIOCHEMISTRY OF NITROGEN IN THE SYNTHESIS OF ACTIVATED SLUDGE *

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Activated sludge has long been recognized as a very efficient means of removing organic material from solution. The removal of organics is brought about by two processes, oxidation and synthesis. In the oxidation process, organic carbon is converted to carbon dioxide. In the synthesis process, organic carbon is incorporated into the formation of new bacterial cells. It is through this second process that the activated sludge mass maintains and even increases itself.

Bacterial synthesis is a complex procedure. From the substrate on which the bacterium is grown, all of the complex enzymes, co-enzymes, and metabolic intermediates must be formed. These compounds are all organic in nature, consisting of carbon, hydrogen, oxygen, and sulfur. Inorganics also play an important role in bacterial synthesis. Cations, such as sodium, calcium, and magnesium, are necessary in trace amounts as enzyme activators; phosphates are needed in somewhat larger amounts as constituents of energy transfer enzymes; and nitrogen is needed in even larger quantities for the formation of amino acids and proteins in the cells. A well-balanced substrate is necessary to allow unrestricted growth of bacterial cells.

Because synthesis and the need for nitrogen are directly related, it is seen that the amount of synthesis an activated sludge mass undergoes while stabilizing organic matter is directly related to the nitrogen requirement of that sludge. If sludge synthesis can be controlled, the nitrogen demand can also be controlled. However, because the equation for removal of organics is

$$\text{Total Removal} = \text{Oxidation} + \text{Synthesis}$$

the reduction of synthesis necessitates an increase in oxidation if total removal is to remain the same.

The importance of controlling the amount of nitrogen that must be added to nitrogen-deficient industrial wastes is increasing as the scope of industrial waste treatment expands. Inasmuch as the sanitary engineer must fortify wastes as economically as possible, this study was made to investigate the removal of organic material from solution by a low synthesis-high oxidation —therefore, low nitrogen demand—system. In order to understand fully the relationships involved, the use of ammonia-, nitrate-, and nitrite-nitrogen for activated sludge synthesis was investigated.

### Theoretical Considerations

The object of biological treatment for the stabilization of organic material is the removal of the carbon in the organic matter that exists in the waste stream before it is discharged into the receiving body of water. This treatment process, as it is known today, consists of passing the waste through an ac-

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tivated sludge aeration tank or over the stones of the trickling filter. As this is done, two processes come into play; one of oxidation and one of synthesis. The sum of these two processes is the total removal of carbon from the waste stream. Using acetate as the organic source, the equation would be:

$$3C_2H_4O_2 + \tfrac{1}{4}O_2 + \text{Nitrogen Source} \rightarrow CO_2 + 2\tfrac{1}{2}H_2O + C_5H_7O_2N \quad (1)$$

At this stage of the treatment process all of the carbon has been removed from the waste stream, but only 1/6 has actually been lost from the system. The remaining 5/6 must still be dealt with.

One method of dealing with the daily sludge growth is to waste excess sludge to the digester. This is a poor solution for two reasons: (a) it involves the operation of a second biological unit to complete the destruction of the carbon initially in the waste stream, and (b) it involves the loss from the aerobic portion of the treatment system of the nitrogen contained in the bacterial protein.

The other method of dealing with the excess sludge formed is to return it all to the aeration tank. If this is done, the aeration solids will continue to increase in mass until, at equilibrium, the solids are being oxidized by endogenous respiration in the same quantity as they are being synthesized. This solution has merit for two reasons: (a) it allows all of the carbon in the waste stream to be oxidized in the aeration tank and, therefore, to be truly lost from the system, negating the need for further treatment; and (b) it allows the nitrogen contained in the bacterial protein to be recycled for further use in bacterial synthesis. In other words, Eq. 1 is followed by

$$C_5H_7O_2N + 5\,O_2 \rightarrow 5CO_2 + 2H_2O + NH_3 \quad (2)$$

$$3C_2H_4O_2 + O_2 + NH_3 \rightarrow CO_2 + 4H_2O + C_5H_7O_2N \quad (3)$$

and summation of Eqs. 2 and 3 gives

$$3C_2H_4O_2 + 6\,O_2 \rightarrow 6CO_2 + 6H_2O \quad (4)$$

Eq. 4 shows all the original carbon being lost from the system as carbon dioxide, and also shows that no additional nitrogen is needed to maintain the system, once equilibrium is reached.

It has been established in the literature that nitrogen enters synthesis reactions at the oxidation level of ammonia. Therefore, if any other nitrogen source except ammonia is to be utilized for bacterial synthesis, it first must be converted to ammonia before it is available. There are well defined over-all reactions (some intermediates unknown) which show the conversion of nitrate- and nitrite-nitrogen to ammonia. These other two forms of nitrogen are, therefore, available for use in the production of bacterial protoplasm.

When ammonia-nitrogen is taken into the cell for synthesis it is linked with carbon, hydrogen, oxygen, and sulfur to form amino acids, which are in turn linked together to form proteinaceous material. When the cell dies, it lyses and releases the nitrogenous material back into solution. The organically-bound nitrogen is then available for further use by other bacteria for synthesis, if it can be split out of its complex molecule.

Inasmuch as all of the organic transformations that take place inside a bacterial cell except one, the production of certain polysaccharides, are reversible, all but one compound that a cell synthesizes can be degraded. Therefore, all of the complex proteins and amino acids produced by a cell during its synthesis and released into solution at death by lysis can be broken down by other cells and the nitrogen utilized as the demand arises.

## Apparatus and Procedure

The object of this study was to investigate the effect which various meth-

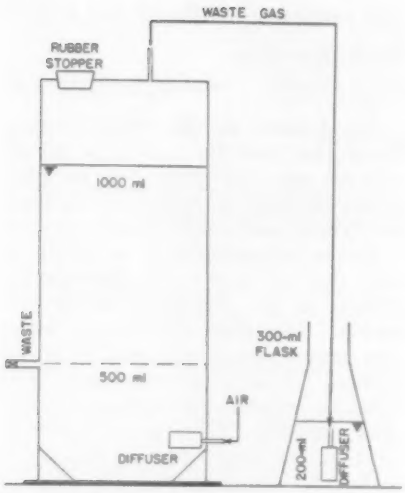


**FIGURE 1.—Batch-fed aeration unit with waste gas trap.**

ods of nitrogen supplementation would have on the biochemistry of nitrogen in the synthesis of activated sludge. It was important to choose a laboratory model that would closely duplicate conditions occurring in practice today so that the results would have practical application. Typical field practice consists of long, narrow activated sludge aeration tanks which are fed at the influent end only, have air supplied by diffusers along one of the long sides of the tank, and have the secondary sludge returned to the influent end of the aeration tank.

To reproduce these conditions in the laboratory, aeration units as shown in Figure 1 were selected. Each compartment was a fill-and-draw unit 12 in. high, 2 in. wide, and 5 in. deep. The capacity of each compartment was 1.5 l, with provision made for drawing off 1 l of effluent after settling.

Air was supplied at about 15 psi through a porous diffuser in the lower back corner of each compartment. This produced a rolling effect similar to that in full-scale plants. The units were operated at room temperature, which was fairly constant at 23°C.

During the early stages of the investigation these units were open to the atmosphere. Later, in an attempt to trap any ammonia-nitrogen stripped from solution during aeration, the units were capped, as shown in Figure 1, and the waste gas bubbled through 200 ml of slightly acidified distilled water.

Experimental techniques were employed which would evaluate the relationship of nitrogen requirements of activated sludge to the synthesis in activated sludge. Activated sludges stabilizing a completely nitrogen-deficient organic waste were supplemented with three forms of nitrogen: ammonia, nitrate, and nitrite. The changing level of aeration solids was noted to determine the synthesis occurring in the systems. This was correlated with the nitrogen requirements as determined by a complete nitrogen balance.

To make this balance as complete as possible, all forms of nitrogen in the effluent—the increase of nitrogen in the sludge, and the ammonia-nitrogen blown out of solution—were measured. In addition, the general condition of the system was watched to note any adverse effects which the superimposed conditions might have on over-all operation. The usual parameters—pH, chemical oxygen demand and biological solids in the effluent, and microscopic condition of the sludge—were used as a measure of over-all operation.

At the end of each phase of study the amino acid content of the sludges from each system was determined by the two-phase paper chromatography technique, and the chemical composition of the volatile portion of sludges was determined by microchemical analysis. These analyses completed the investigation of the effect of various methods of operation on the nature of the activated sludges.

All systems were grown on a sodium acetate substrate, 1,000 mg/l as acetic acid. Sufficient quantity of the proper nitrogen salt was added to the systems to supply 50 mg/l of nitrogen. In the ammonia-nitrogen systems, ammonium

sulfate was added; in the nitrate-nitrogen systems, sodium nitrate was added; and in the nitrite-nitrogen systems, sodium nitrite was added. Cambridge, Mass., tap water was used throughout the investigation and supplied all the trace elements necessary for unrestricted bacterial growth, except phosphorus. To supply the needed phosphorus and to buffer the systems, 1,000 mg/l of potassium mono-basic phosphate was added to all systems.

To start the systems, sufficient activated sludge was developed on ample nitrogen (50 mg/l). The day the test was to begin the sludge was evenly distributed among five units and the regular testing program was begun. Each of the five units was fed a different amount of nitrogen of the form being tested. The feeding schedule was as follows: Unit 1, 50.0 mg/l N added (control); Unit 2, 37.5 mg/l N added; Unit 3, 25.0 mg/l N added; Unit 4, 12.5 mg/l N added; and Unit 5, 0.0 mg/l N added. All units were aerated for 23 hr, settled for 1 hr, and operated with 100 per cent secondary sludge return. The test lasted 35 days and each unit was sampled every fifth day (seven times during the test) and allowed to regain equilibrium during the interim four days.

## Experimental Results

### *Ammonia-Nitrogen Systems*

All five of the units operated well throughout the five weeks of the testing, as shown by a low chemical oxygen demand in the effluent on each day of testing. The volatile biological solids in the mixed liquor (Figure 2) increased throughout the test period for

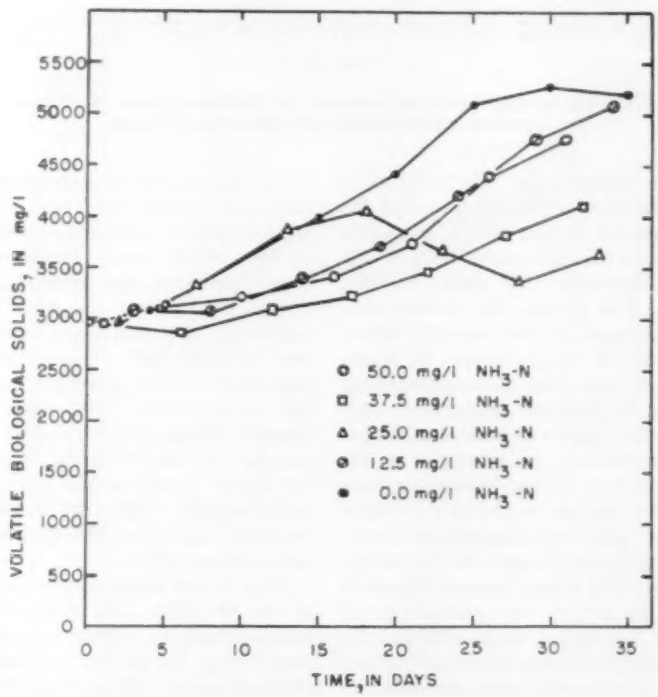


FIGURE 2.—Volatile biological solids in the mixed liquor of systems supplemented with ammonia-nitrogen.

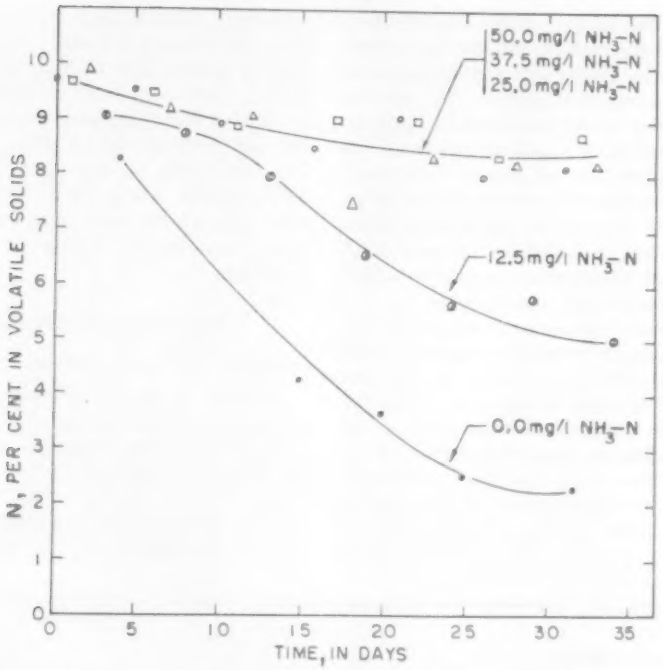


FIGURE 3.—Percentage of nitrogen in volatile portion of sludge in systems supplemented with ammonia-nitrogen.

all units except one. Unfortunately, insufficient data were taken during the 10-day period during which the solids declined in the 25.0-mg/l $NH_3$-N system to determine the cause for the decline. The system did recover and the solids began to rise normally before the end of the run, however. It is significant to note that the system which produced the greatest quantity of solids was the one which received no nitrogen.

The percentage of nitrogen in the volatile portion of the sludge in each of the five systems is shown in Figure 3. These data were obtained by dividing the organic nitrogen in the sludge by the volatile mixed liquor biological solids. Therefore, the percentage of nitrogen in the sludges reflects the organic nitrogen content of the systems. Within experimental error the data for the 50-, 37.5-, and 25-mg/l systems were the same, indicating similar operation. With less nitrogen being added to the 12.5-mg/l system, the organic nitrogen in the system could not increase; but, as the mixed liquor biological solids were increasing, the percentage of nitrogen went down. In other words, a somewhat nitrogen-lean sludge mass was being formed. This situation was accentuated even more in the system fed no nitrogen. Not only did the organic nitrogen in the system decrease due to slow loss with the effluent, but the mixed liquor solids also increased quite rapidly. Both of these effects combined to lower the percentage of nitrogen greatly.

Most of the excess ammonia-nitrogen in the 50-, 37.5-, and 25-mg/l systems was oxidized to nitrite-nitrogen, with some being completely oxidized to nitrate-nitrogen. With most of the inorganic nitrogen in the oxidized forms, very little ammonia-nitrogen was aer-

ated directly from solution, even though the pH was about 8.3. Only about 1 mg per day was lost by direct aeration. Still, much unmeasured nitrogen was leaving these systems, as indicated by nitrogen balances. Nitrogen gas denitrified from solution was the only nitrogen quantity which could not be measured. Warburg respirometer tests indicated that the systems were so well acclimated to the substrate that the rate of oxygen demand for the first 30 min after feeding was about 600 mg/l per hr. This demand could not be met by aeration in the pilot plant and nitrite- and nitrate-oxygen were utilized by the microorganisms, with the corresponding release of nitrogen gas. In the 12.5- and 0-mg/l systems no excess nitrogen was present in the effluent.

At the end of the testing period each of the sludges was microscopically examined by staining with Alcian blue GN150 and counterstaining with carbol fuchsin. All of the sludges showed bacterial floc with some fungi. The most striking difference in the systems was the gradual increase in the polysaccharide material in the sludge mass as the amount of nitrogen fed decreased. Very little polysaccharide material was found in the 50-mg/l sludge; but in the 0-mg/l system very little protoplasm was in evidence, whereas the polysaccharide content was very high.

The number of identifiable amino acids in the systems grown on ammonia-nitrogen were as follows:

| $NH_3$–N (mg/l) | Amino Acids |
|---|---|
| 50 | 17 |
| 37.5 | 17 |
| 25 | 17 |
| 12.5 | 14 |
| 0 | 12 |

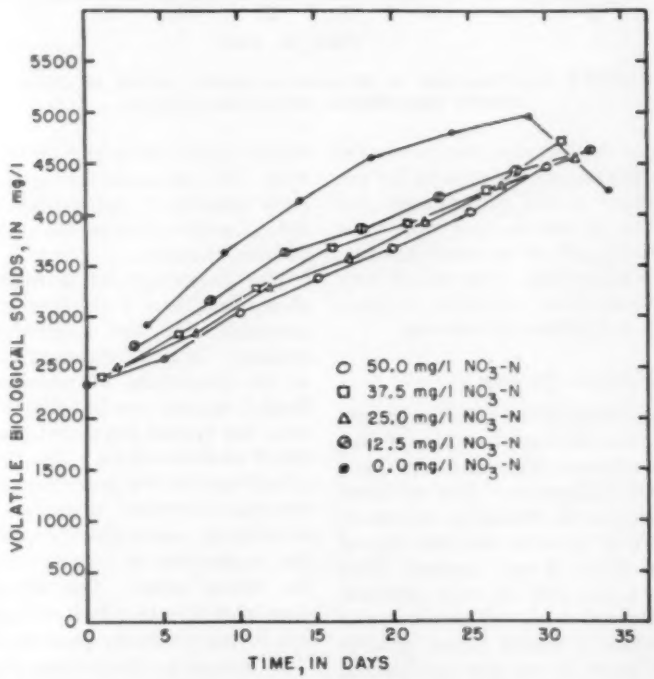


FIGURE 4.—Volatile biological solids in the mixed liquor of systems supplemented with nitrate-nitrogen.

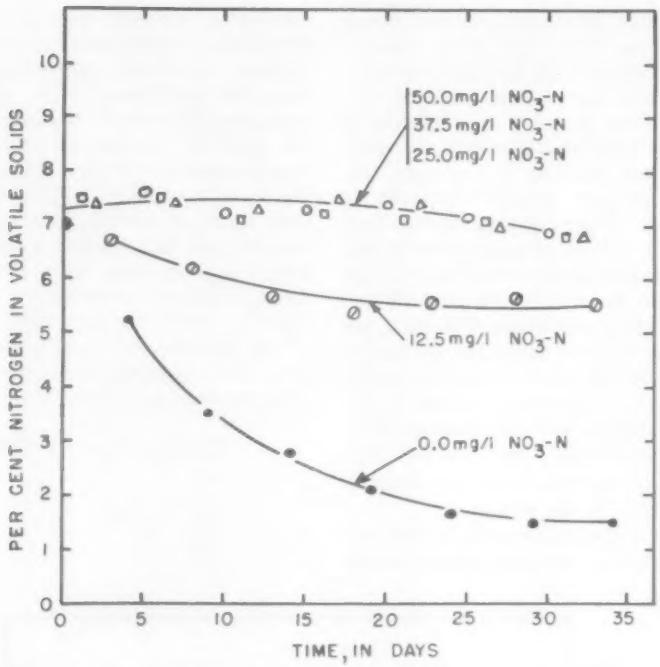


FIGURE 5.—Percentage of nitrogen in volatile portion of sludge in systems supplemented with nitrate-nitrogen.

In spite of the fact that the system fed 0-mg/l nitrogen only contained 2.3 per cent nitrogen in the sludge at the end of the run, 12 amino acids were present, including all of the essential ones; thus indicating that, even under very rigorous conditions, the range of amino acids is not significantly reduced.

*Nitrate-Nitrogen Systems*

The operation of the nitrate-nitrogen systems was similar to that of the ammonia-nitrogen systems except for a few minor differences. One of these differences was the lack of good organic removal in 23 hr after the 24th day of operation of the 0-mg/l system. This was shown, not only by high chemical oxygen demand in the effluent, but also by a decline in mixed liquor volatile solids (Figure 4) on the last testing day. Before that time, however, Figure 5 shows a pattern similar to the mixed liquor solids curves for the systems fed ammonia-nitrogen, all systems showing a solids rise with the 0-mg/l system showing the greatest production of solids.

The percentage of nitrogen curves shown in Figure 5 are similar to those presented for the ammonia-nitrogen systems. It is interesting to note that as the percentage of nitrogen in the 0-mg/l system reached about 1.5 per cent, the system developed poor operational characteristics. The percentage of nitrogen in this zero nitrogen system decreased further than in the corresponding ammonia-nitrogen system, due to the loss of organic nitrogen in the effluent solids. The effluent solids were high due to a lack of higher animal forms caused by poor seed.

No ammonia-nitrogen was detected in the systems and only a trace was collected from the waste air. In addition,

no reduction from nitrate to nitrite was detected. Again, however, a nitrogen balance revealed some unaccounted-for nitrogen leaving the system, indicating a nitrogen gas loss during the early part of the aeration period when the oxygen demand was high. In the 12.5- and 0-mg/l systems no inorganic nitrogen forms were found in the effluents.

The Alcian blue stains of the sludges at the end of the test again showed an increase in polysaccharide material as the quantity of nitrogen fed decreased. The 50-mg/l system showed only a small amount of polysaccharide material in the sludge mass, whereas the 0-mg/l system showed little living material but much accumulated polysaccharide.

The number of identifiable amino acids in the systems grown on nitrate-nitrogen were as follows:

| $NO_3-N$ (mg/l) | Amino Acids |
|---|---|
| 50 | 16 |
| 37.5 | 15 |
| 25 | 15 |
| 12.5 | 15 |
| 0 | 10 |

In the 0-mg/l unit only 1.5 per cent nitrogen existed in the sludge and the unit had ceased good operation, but still 10 amino acids were present in the sludge, indicating again the maintenance of a wide variety of amino acids under restrictive conditions.

### *Nitrite-Nitrogen Systems*

The nitrite-nitrogen systems were operated at the same time as those supplemented with nitrate-nitrogen and, therefore, could only be tested four times during the 35-day test period.

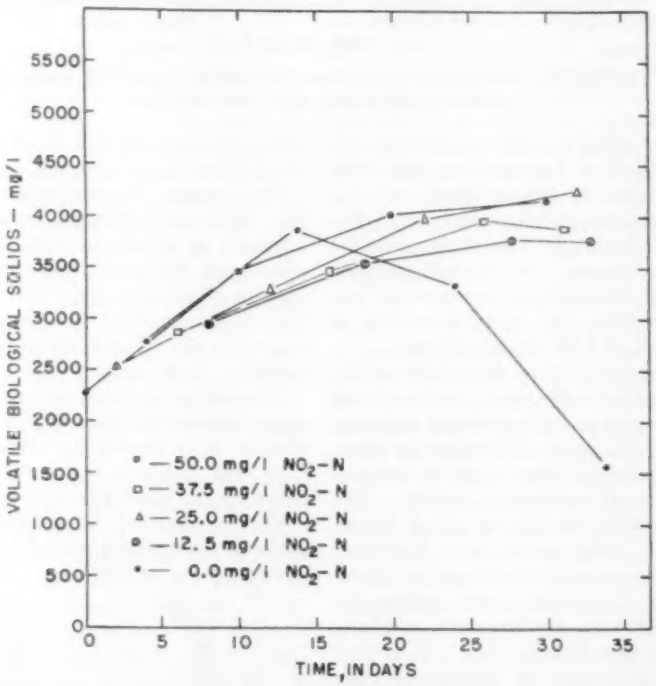


FIGURE 6.—Volatile biological solids in the mixed liquor of systems supplemented with nitrite-nitrogen.

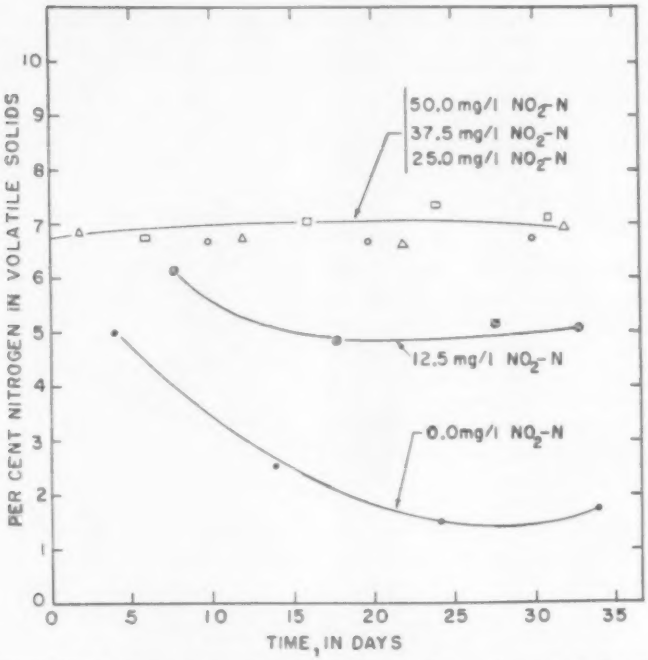


FIGURE 7.—Percentage of nitrogen in volatile portion of sludge in systems supplemented with nitrite-nitrogen.

This was often enough, however, to establish the fact that these systems were quite similar to the ammonia- and nitrate-nitrogen systems previously discussed. As in the case of the nitrate-nitrogen system, the 0-mg/l nitrite-nitrogen system failed in operation before the 24th day, as evidenced by a high level of COD in the effluent.

The mixed liquor biological solids data shown in Figure 6 produced the same pattern as with previous nitrogen forms. The prime difference in these systems was the more complete collapse of the 0-mg/l nitrogen system. Before the sharp decline in mixed liquor biological solids in this unit, however, the solids were developing at a faster rate than any of the other systems, in agreement with the ammonia- and nitrate-nitrogen systems.

The percentage of nitrogen in the sludge (Figure 7) showed the same patterns seen in the previous studies, indicating that the mechanism of operation of all three sets of systems was similar.

The excess nitrite-nitrogen in the 50-, 37.5-, and 25-mg/l systems was oxidized to nitrate-nitrogen, some of which was denitrified, with the resulting loss of nitrogen gas. The 12.5- and 0-mg/l systems had no inorganic nitrogen in the effluent, as there was no excess in these cases.

The Alcian blue stains of the sludges again showed the increase of polysaccharide with decreasing nitrogen fed. This also followed the pattern established by the other two nitrogen forms.

The number of identifiable amino acids in the systems grown on nitrite-nitrogen were as follows:

| $NO_2$–N (mg/l) | Amino Acids |
|---|---|
| 50 | 16 |
| 37.5 | 14 |
| 25 | 15 |
| 12.5 | 16 |
| 0 | 10 |

As before, the amino acid content remained fairly high in spite of the low nitrogen content of the 0-mg/l nitrite-nitrogen system.

## Discussion of Results

### *Relationship of Nitrogen and Synthesis in Activated Sludge*

Conventional activated sludge as it is known in field practice today consists of a long narrow flow-through aeration tank followed by a settling basin. A portion of the activated sludge floc which settles out in the settling tank is returned to the head end of the aeration tank to be mixed with the incoming waste. The mixture is aerated as it passes through the tank, then flows to the settling basin, where the flocculant material separates itself from the liquid. The batch-fed laboratory models used in this investigation represent an ideal (no lengthwise mixing) conventional activated sludge plant.

McKinney (1) reported that activated sludge must be in a state of endogenous respiration if flocculation is to take place. This means that the organic level in solution surrounding the organisms must be in equilibrium with the concentration of organic material inside the bacterial cells. At this low level of organic material in solution the bacteria derive energy from the destruction of part of the sludge mass. This is the condition of the sludge mass as it settles in the clarifier; activity and number of active organisms are low. The settled sludge is then collected and returned to the head end of the aeration tank.

At this point the organisms and substrate are mixed, the food-to-active microorganism ratio is increased enormously, and the organisms change from the endogenous phase of their life cycle to the growth phase. With the sludge in the growth phase and the food-to-microorganism ratio high, rapid rates of organic removal are effected, with a corresponding high demand for oxygen and a great increase in sludge mass. Porges, Jasewicz, and Hoover (2) wrote the theoretical equation for the removal of skim milk (lactose and casein) as follows:

$$8\,CH_2O + C_8H_{12}N_2O_3 + 6\,O_2 \rightarrow 2\,C_5H_7NO_2 + 6\,CO_2 + 7\,H_2O \quad (5)$$

By measuring the oxygen uptakes and the chemical oxygen demand removed they computed how much substrate had been oxidized and synthesized. As these values did not balance, they assumed that some substrate must have been taken into the cells and stored. This conclusion was based on the assumption that the ratio of substrate oxidized and synthesized remained constant, as shown in Eq. 5, throughout the aeration period. They felt that the stored material remained inside the cell as the polysaccharide, glycogen.

As the mixed liquor passes through the aeration tank the organic substrate is rapidly removed. Only a portion of the carbon, however, is converted to carbon dioxide and lost from the system; the rest is in new cells or stored material. According to Porges *et al.* (2), the sludge begins to oxidize the stored material as food in solution becomes limiting. After the stored material is consumed, true endogenous respiration starts. The sludge mass consumes itself at the rate of about 1 per cent of its own weight per hour. Therefore, if sufficient time is allowed in the aeration tank the sludge mass will return to its original level, ready for the next cycle. This means that, although conditions are always changing in the conventional activated sludge aeration tank and the microorganisms are in a constant state of flux, the sludge, given time, will oxidize itself back down to the original solids level.

The results of this investigation indicate a different mechanism of operation of batch-type activated sludge systems than that of Porges *et al.* (2). Studying systems with no wasting of return secondary sludge (aeration solids level and aeration period approximately the

TABLE I.—Comparison of Activated Sludge Systems Grown on Three Forms of Nitrogen

| N Added | | N in Sludge Vol. Sol. (%) | | Formula |
|---|---|---|---|---|
| Type | Conc (mg/l) | Init. | Final | |
| $NH_3-N$ | 50 | 9.7 | 8.2 | $C_7H_{12}O_4N$ |
| | 37.5 | 9.8 | 8.7 | $C_7H_{12}O_4N$ |
| | 25 | 9.9 | 8.3 | $C_6H_{11}O_4N$ |
| | 12.5 | 9.1 | 5.0 | $C_{10}H_{15}O_6N$ |
| | 0 | 8.3 | 2.1 | $C_{28}H_{42}O_{14}N$ |
| $NO_2-N$ | 50 | 7.0 | 6.9 | $C_9H_{12}O_5N$ |
| | 37.5 | 7.5 | 6.8 | $C_8H_{14}O_5N$ |
| | 25 | 7.4 | 6.8 | $C_9H_{14}O_5N$ |
| | 12.5 | 6.7 | 5.5 | $C_{10}H_{15}O_6N$ |
| | 0 | 5.2 | 1.5 | $C_{31}H_{60}O_{20}N$ |
| $NO_3-N$ | 50 | 6.6 | 6.7 | $C_9H_{15}O_5N$ |
| | 37.5 | 6.7 | 7.1 | $C_8H_{14}O_5N$ |
| | 25 | 6.8 | 6.9 | $C_7H_{17}O_5N$ |
| | 12.5 | 6.1 | 5.0 | $C_{11}H_{19}O_9N$ |
| | 0 | 5.0 | 1.8 | $C_{20}H_{32}O_{20}N$ |

same as suggested by Porges *et al.* (2)), an increase in volatile aeration solids was recorded throughout the entire 35 days of operation for all well-operating systems.

The comparison of all of the systems grown on the three forms of nitrogen is shown in Table I. It is seen that in most systems the percentage of nitrogen in the sludge mass decreased throughout the test. This was particularly evident in the 12.5- and 0-mg/l added systems. Correspondingly, by the end of the runs all of the empirical formulas of the sludge masses deviated for the $C_5H_7O_2N$ formulation reported by Porges *et al.* (2). This deviation was the greatest in the two lowest nitrogen added systems.

In spite of the wide range of formulations, the ratio of C : H : O (exclusive of nitrogen) remained practically constant for all systems. The range of ratios was $C_{1.0}:H_{1.67}:O_{0.56}$ to $C_{1.0}:H_{1.86}:O_{0.82}$, with most of the formulations following the $C_{1.0}:H_{1.7}:O_{0.6}$ ratio. This indicated the build-up of very similar material in all systems. Microscopic examination of the Alcian blue stained slides of the sludges showed this material to be predominantly extracellular polysaccharide.

The formulas in Table I are for the total sludge mass, not the individual bacterial cells contained therein. Bacterial cells taken from the 50-mg/l $NO_2$–N added system were grown on tryptone glucose agar, harvested, and submitted for microchemical analysis. The formulation of these bacterial cells was $C_5H_8O_2N$, as contrasted to the formulation of the sludge mass as a whole of $C_9H_{16}O_5N$. The bacterial formula agreed well with the work of Porges *et al.* (2) and confirmed the concept of a build-up of polysaccharide material in the over-all sludge mass.

Porges *et al.* (2) reported that the stored material in their sludge was an internal insoluble glycogen-like substance, which was metabolized when the substrate concentration in solution was lowered. Oginsky and Umbreit (3) pointed out that the polysaccharide often was accumulated as a waste product of internal metabolism. As waste product, this material would not be subject to further biological action. This was the situation in the investigation described herein. External waste products in the form of polysaccharide material slowly accumulated in the sludge mass throughout the run. This material was resistant to biological degradation; otherwise it would have been utilized during the long period of endogenous respiration that occurred each day.

Figure 8 shows how this polysaccharide material accumulated in solution. In a typical system fed high nitrogen, the high demand for synthesis was mostly met by the formation of true protoplasm, $C_5H_7O_2N$ (dimension A), with very little of the substrate processed through the cell and immediately discharged as waste product (dimension B). The increase in total sludge mass is the algebraic sum of the protoplasm and polysaccharide formed. What little polysaccharide was formed was metabolized slowly, if at all, and a

high percentage remained in the sludge mass after 23 hr (dimension D). On the other hand, the large quantity of true protoplasm formed underwent endogenous metabolism during the remainder of the aeration period, and at the end of aeration showed only a modest increase in weight (dimension C). Repeated day after day, this system would show a steady increase in protoplasm (organic nitrogen in the sludge), in polysaccharide (slowly decreasing percentage nitrogen in the sludge), and in total mass of aeration solids.

Examples of high-nitrogen systems in this investigation were as follows:

| $NH_3-N$ Added (mg/l) | $NO_2-N$ Added (mg/l) | $NO_3-N$ Added (mg/l) |
|---|---|---|
| 50.0 | 50.0 | 50.0 |
| 37.5 | 37.5 | 37.5 |
| 25.0 | 25.0 | 25.0 |

Due to the lack of higher animal forms in the nitrite-nitrogen systems the effluent from these systems was very turbid. This daily loss of solids prevented the natural build-up of aeration solids. The restricted aeration solids growth prevented the decline in the percentage of nitrogen in the sludge typical of high-nitrogen systems (Table I). The other two criteria were met by these systems, however.

Figure 9 shows the situation in a system to which a moderate quantity of nitrogen was being added. The stimulation for synthesis was the same because the same quantity of organic material was being added (same food-to-microorganism ratio), but the restricted amount of nitrogen being added prevented a high quantity of true protoplasm from being formed. The microorganisms compensated by processing just as much substrate but discharging more waste products which require no nitrogen (dimension B). As aeration proceeded, the true protoplasm formed could be degraded back to the initial level but the level of aeration solids would continue to rise due to the very slow decomposition (accumulation) of

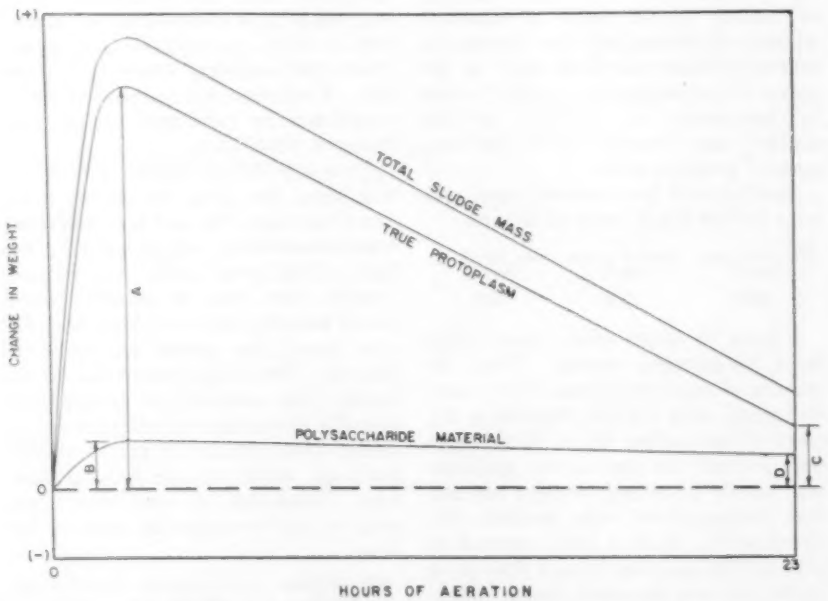


FIGURE 8.—Synthesis changes in high-nitrogen systems.

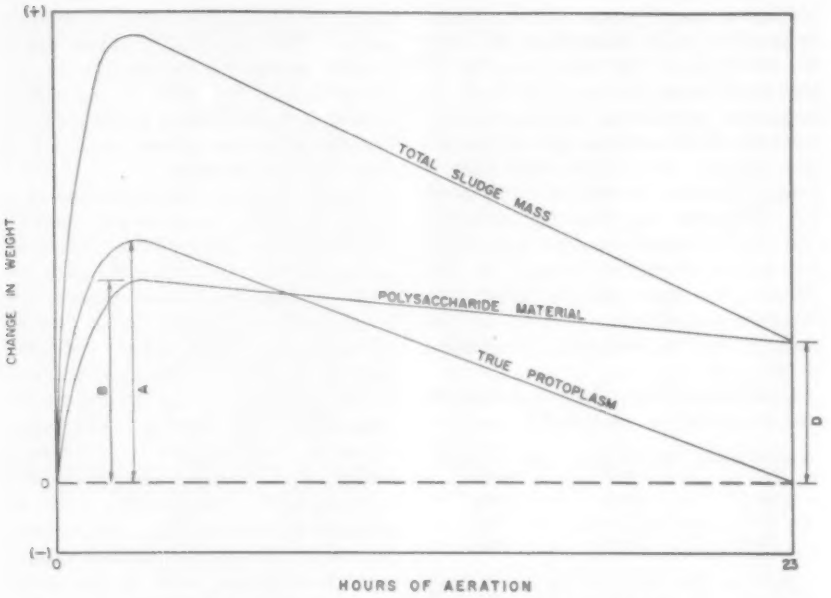


**FIGURE 9.—Synthesis changes in moderate-nitrogen systems.**

polysaccharide (dimension D). During a long period of operation this type of system would show a constant amount of protoplasm (no change in organic nitrogen in the sludge), an increase in polysaccharide (rapid decline in percentage of nitrogen in the sludge), and a marked rise in the total mass of aeration solids.

Examples of moderate-nitrogen systems in this study were as follows:

| $NH_3$–N Added (mg/l) | $NO_2$–N Added (mg/l) | $NO_3$–N Added (mg/l) |
|---|---|---|
| 12.5 | 12.5 | 12.5 |

Figure 10 shows what would occur in a low-nitrogen system. With the amount of true protoplasm which could be formed, very limited (dimension A), most of the carbon which would have been utilized for protoplasm synthesis was merely processed through the cell and discharged as waste product (dimension B). Such a small amount of true protoplasm was formed that more protoplasm was degraded during endogenous respiration than was synthesized during metabolism. It is important to remember that this mechanism could only occur in a well-established system with a high quantity of protoplasm which was suddenly starved of nitrogen. A well-operating activated sludge could not be developed under low-nitrogen conditions.

This is a dying system, protoplasm was being lost from the system every day (dimension C), and polysaccharide was accumulating (dimension D). Because of this great build-up of polysaccharide, the level of aeration solids would actually increase (dimension E), even though the system was being destroyed. The organic nitrogen in the sludge (the measure of protoplasm) and the percentage of nitrogen in the sludge (the measure of polysaccharide build-up) would sharply decrease, however. Examples of low-nitrogen systems in this investigation were as follows:

| $NH_3$–N Added (mg/l) | $NO_2$–N Added (mg/l) | $NO_3$–N Added (mg/l) |
|---|---|---|
| 0 | 0 | 0 |

*Practical Application*

1. Batch-fed and long narrow conventional activated sludge systems cannot operate with no wasting of return sludge without having some increase in sludge mass. If the mixed liquor were aerated long enough to destroy the polysaccharide fraction of the sludge mass, the true protoplasm in the system, which is degraded much faster, would show a net decrease after the long aeration period, and the system would destroy itself. Reports in the literature which indicate no waste operation with no increase in solids probably were in error due to the omission in the solids balance of the solids in the effluent. Even a small concentration of effluent suspended solids can represent a large solids loss over a long period of time.

2. The most efficient method of supplementing a batch-fed or conventional activated sludge system is one which creates the conditions shown in Figure 9. In this moderate-nitrogen system there is no daily decrease in true protoplasm, therefore the system is maintaining itself; but the high nitrogen demand for synthesis near the beginning of the aeration period is held to a minimum. This condition can best be met in the field by keeping the organic nitrogen in the sludge, as measured by the Kjeldahl nitrogen technique, at a constant level. Maintenance of the inorganic nitrogen in the effluent at a low level will not accomplish satisfactory results. As the microorganisms which must be synthesized each day to meet the moderate-nitrogen condition lyse and release their protein material to solution, the amino ($NH_2$) groups contained therein will be split off as ammonia-nitrogen, which will pass out with the effluent, either directly or in an oxidized-nitrogen form. If inorganic nitrogen were absent from the effluent, this would mean insufficient nitrogen was being supplied to the system to allow the proper amount of protoplasm synthesis.

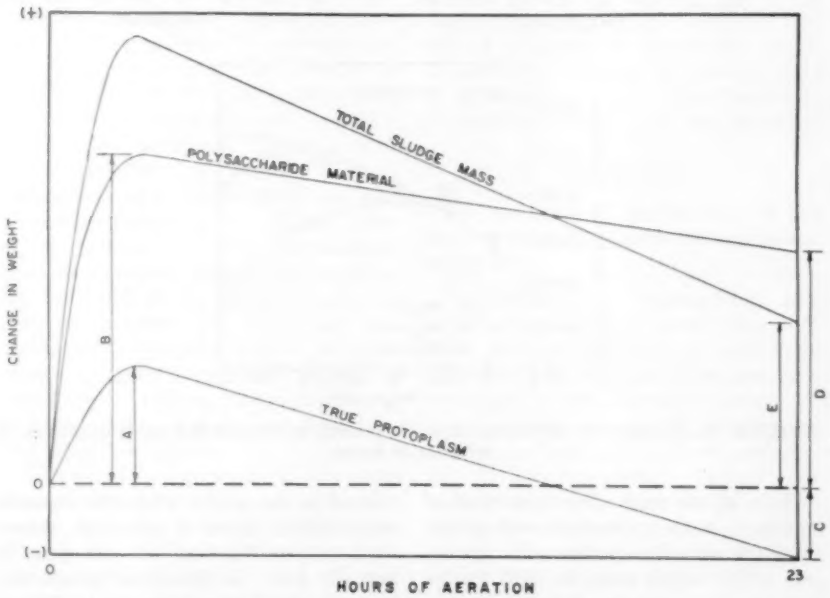


FIGURE 10.—Synthesis changes in low-nitrogen systems.

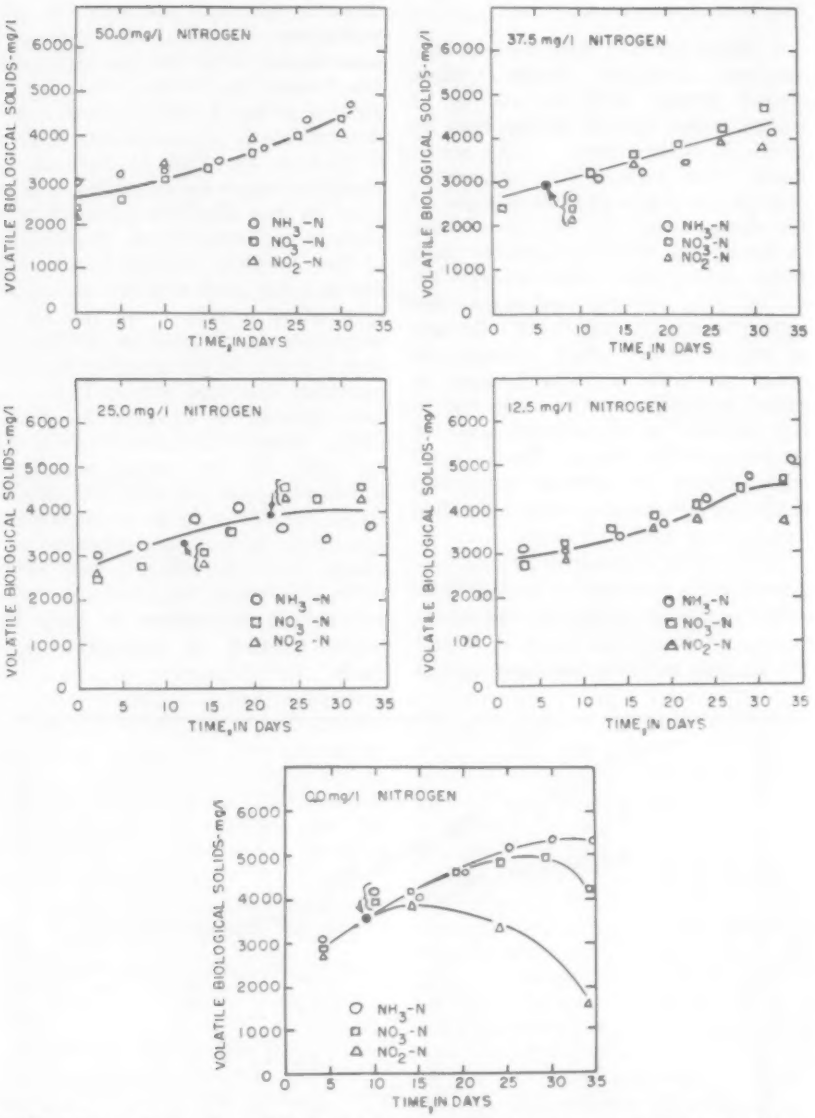


FIGURE 11.—Comparison of biological solids growth in systems fed equal quantities of different N forms.

Even at the most efficient method of operation, some protoplasm will be lost from the aeration system with the excess solids which must be bled to the digester to prevent aeration solids build-up. This nitrogen will be returned to the system when the digester supernatant liquor is recycled; therefore, at equilibrium no nitrogen is actually lost. In this investigation the systems which met these most efficient conditions were the 12.5-mg/l nitrogen

added systems. These systems showed a nitrogen requirement of 1.17 lb N per 100 lb of COD removed and had a COD/N ratio of 85/1.

3. From the standpoint of over-all operation as measured by the volatile biological solids in the mixed liquor, all forms of inorganic chemical nitrogen seem to be equally effective for supplementation, as shown in Figure 11. Although no attempt was made to adjust the aeration solids levels of the units, within experimental error all systems being fed the same quantity of the three forms of nitrogen came to the same level of aeration solids in the cases where nitrogen was not limiting. In the 0-mg/l nitrogen case, the difference between the three systems can be traced to turbidity in the effluent. The system that lost the most solids failed first, and so on. It is significant to note that, before failure began, all three systems were growing at the same rate.

Economics always lie with ammonia-nitrogen for supplementing a nitrogen-deficient waste; but if high pH conditions occur and much ammonia-nitrogen is being blown out of solution, nitrate- or nitrite-nitrogen could be equally well used. In addition, if one of the oxidized-nitrogen forms existed in an industrial waste in sufficient quantity, it would be uneconomical and unnecessary to add ammonia-nitrogen also. If the waste being treated is easily assimilable, causing excessive oxygen demands at the head-end of the aeration tank, the use of nitrate- or nitrite-nitrogen would be a valuable source of additional oxygen to prevent anaerobic conditions. Under these conditions, however, some nitrogen gas would be lost from the system.

The extra energy required to reduce the oxidized-nitrogen forms to the ammonia level for synthesis makes them slightly less available for supplemental purposes than ammonia itself. This is shown by the somewhat lower nitrogen content of the sludges grown on nitrate- and nitrite-nitrogen (Table I).

4. Batch-fed or conventional activated sludge systems are wasteful of nutrients. Ample nitrogen must be supplied to meet the high synthesis demand at the start of the aeration period or there will be a net loss in protoplasm. On the other hand, as the synthesized sludge is degraded during the remainder of the aeration period, the nitrogen in the sludge is released, to be blown out of solution or lost in the effluent. Even if the most economical condition is met, some polysaccharide will accumulate, causing the necessity of wasting sludge to the digester. The digester, however, is merely another biological device in which polysaccharide is no more rapidly broken down than in the aeration tank. High polysaccharide content also interferes with vacuum filtration. In addition, this economical condition is difficult to meet and control in the field. An obvious improvement in operation would be to modify the activated sludge process to prevent the high synthesis of sludge followed by degradation of the same sludge. The use of a system in which the microorganisms are always in a steady state of equilibrium, rather than constantly fluctuating, would meet this criterion.

## Conclusions

On the basis of the findings in this investigation, the following conclusions are drawn:

1. Batch-fed or conventional activated sludge systems must have sufficient nitrogen supplied to satisfy the high synthesis demand which occurs at the start of each aeration period. If this synthesis demand is not met, excess protoplasm will be destroyed during the aeration period. The nitrogen incorporated into the sludge during synthesis will be largely lost to the system when the sludge is degraded later in the aeration period.

2. Batch-fed or conventional activated sludge systems cannot operate

without wasting and without a gradual solids build-up unless some solids escape with the effluent.

3. All inorganic, chemical nitrogens are available for nitrogen supplementation. Ammonia-nitrogen will be aerated from solution at high pH, whereas nitrate- or nitrite-nitrogen can be used as an additional oxygen source with the accompanying loss of nitrogen gas. Due to the energy requirements, nitrate- and nitrite-nitrogen are slightly less available for supplementation than ammonia.

### Acknowledgment

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# IMPROVED EQUIPMENT FOR VACUUM FILTRATION OF SLUDGE

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Modern sewage treatment practice is the product of rapid advancements in technology and process improvements, part of which have resulted from plant operators' experience and experimentation. One of the more recent improvements in sewage processing has been the employment of continuous vacuum filtration followed by drying or incineration as a method of sludge disposal. This improvement is the result of new trends toward utilization of the fertilizing values of sewage sludge and the widespread building of homes near treatment plants, which has placed a premium on efficient nuisance-free methods of sludge disposal (1)(2).

Unfortunately, processing equipment has not kept pace with increasing technology, and operational problems with sludge disposal equipment have plagued the operators of many sewage treatment plants. In many cases it has been necessary for the operator to develop chemical and mechanical skills to a high degree in order to keep the equipment functioning properly. Some of the most difficult problems have centered around the filtration step.

## Early Problems

The most common trouble in sludge filtration has concerned chemical conditioning and filter medium blinding. Often the problem of filter medium blinding was the direct result of improper chemical conditioning of the sludge prior to filtration. Erratic flow conditions sometimes resulted in septic sludge or partially digested sludge being fed to the filters. If this condition was not noticed and no additional chemicals were added, rapid blinding of the filter medium occurred and the performance of the filter was greatly decreased. Consequently, many plants were forced to overdose the sludge continuously to prevent rapid cloth blinding when septic conditions arose, thereby incurring high chemical costs. In some cases overdosage with lime resulted in a carbonate buildup within the cloth medium, which necessitated that the filters be shut down periodically for acid rinsing of the cloth.

A second and equally important factor contributing to cloth medium blinding on sludge filters concerned poor cake discharge. Blinding in this case is due to the inability of the conventional drum filter to completely discharge the thin cakes commonly encountered in sewage sludge filtration. As a result of this incomplete discharge, portions of the sludge cake which are not removed at discharge become imbedded within the medium structure and block further filtration or passage of fluids at these points. This condition is more pronounced at caulking or division strips on the conventional drum filter, where the sludge cake usually is thinnest. Once this type of blinding has started, the cohesive forces of the imbedded solids attract additional matter and the blinding progressively increases until one-half of the surface has become plugged with sludge. When cloth blinding has increased to this extent, filtration rates have decreased to the point where the

cloth must be cleaned or replaced to be able to handle the plant flow.

To alleviate this problem as much as possible, many plant operators were forced to run the filters at a very slow speed so as to form a cake of sufficient thickness to be discharged as completely as possible. Even in these cases, however, blinding was merely reduced and not eliminated. Also, due to the use of the slow filter speeds of 6 to 10 min per revolution, the productive capacity of the filtration equipment was minimized, and severe cracking of the cake increased the air requirements of the vacuum pump. Thus, the conventional filter area required to handle a given plant flow must be purposely oversized to account for the reduced rate under conditions of partial blinding or slow filter speed.

Nevertheless, the earlier filters were not without their good points. Due to the tight weave of the cloth medium and the excellent seal obtained when the cloth was caulked to the drum, high vacuum levels were obtained on the cake-forming and dewatering portions of the filter cycle. Operation at high vacuum levels meant that maximum productive capacity and minimum cake moisture content would be obtained, all other variables remaining constant. This was particularly important when a drying or incinerating step followed the filtration operation. Because the cost of fuel has increased rapidly in the past few years, the substantial reduction in cake moisture content obtained when operating at peak vacuum levels has made this type of operation imperative (3). Also, the tight cloth medium produced excellent filtrate clarities (50 to 500 ppm suspended solids) dependent on the condition and weave of the fabric employed, resulting in the minimum solids load being returned to the primary clarifiers.

## Objectives for Improvement

It became apparent, therefore, that a new improved method of filtration was urgently needed in the sewage and industrial waste field. After tabulating both the advantages and disadvantages of existing filtration equipment, several fundamental objectives were selected as definite criteria which must be achieved in a new filter design (4). These fundamental objectives are as follows:

1. Availability of a clean medium at all times.
2. Cake discharge must be such that thin cakes may be removed continuously and cleanly.
3. Blowback of filtrate must not occur.
4. High vacuum levels must be maintained to obtain maximum productive capacity and low cake moistures.
5. Filtrate clarities must approximate the clarity presently obtained on cloth-medium filters.
6. Flocculating reagent dosage must be reduced.

## Theory for Improvement

To eliminate blinding, the two main contributors to this problem must be removed from the operation. The first, buildup of solids within the medium due to incomplete discharge, needs the obvious solution of insuring that a complete discharge is obtained. To do this a unit must be designed which will discharge extremely thin cakes (to $\frac{1}{16}$-in. thickness) cleanly and completely. By designing for operation at this small thickness level, the thinnest sewage cakes will be easily discharged.

One of the best methods to date for discharging thin cakes is passage of the cloth over a roller having a much smaller radius of curvature than the drum on which the filter cake was formed. Thus, the filter cake will tend to follow a path tangent to the point of contact of the medium with the small roller. In so doing, the cake breaks cleanly away from the cloth. Due to the excellent efficiency of this

type of discharge, it was decided that this principle would be incorporated into a new filter design in order that complete cake removal would always be effected on sludge filters.

The second contributor to blinding, chemical buildup within the medium, is more difficult to eliminate because it is a function of the chemical dosage required to flocculate the sludge prior to filtration. If the dosage were reduced to the point where there would be no tendency for chemical buildup to occur, the chances of blinding from unflocculated sludge would increase. Therefore, it was decided to eliminate both problems by employing a new metallic medium that would not blind, but rather would facilitate removal of any included solids by the nature of its structure. This new medium is a woven stainless steel webbing that causes flexure or movement of every wire relative to its neighbor as the belt passes over a small-diameter roller. Thus, any material that might tend to blind the medium is forced to the surface by the flexing movement of the wires. Once at the surface, the foreign matter is easily discharged, and the medium is maintained in a clean condition at all times.

To further insure that no chemical buildup would occur, it was decided to provide facilities for spraying the webbing from both sides, so that cleaning could be done at any time without disturbing the filtration operation or diluting the feed slurry. By providing this facility, the initial wet sludge cake normally encountered at the start-up of filters may be easily washed from the medium if discharge is not complete. Upon shutting down the filter, the medium again may be sprayed from both sides automatically, thus freeing the operator for other duties.

In order that the maximum productive capacity, minimum cake moistures, and good filtrate clarity be obtained, it is necessary that the new filter design maintain an excellent seal between the medium and the drum surface. This is mandatory to insure that there will be no loss of vacuum or passage of solids through leakage at the juncture of the belt and the drum surface. Thus, careful consideration was given to this detail in the design of the new unit to provide a filter which would offer premium operation.

## Design of Rotobelt

From the coupling of the fundamental objectives sought in the proposed new filter and the theory for achieving these objectives, a prototype unit having 25-sq ft area was built and installed near the East Lansing sewage treatment plant for operation under the auspices of Michigan State College.* The basic design of this unit (Figure 1) consists of a drum filter, a discharge roller, wash roller, wash sprays, a wash trough, and a return roller. The woven metallic medium employed on this filter is not caulked to the drum surface, as is done on conventional cloth-covered drum filters, but rather lies on the drum surface until it is transferred to the discharge roller. At this point the formed sludge cake breaks away from the webbing by the action of the small-diameter roller coupled with the flexing action of the belt.

The belt then travels under a wash roller, at which point it may be sprayed or passed through a solvent for removal of any particles from possible chemical buildup at plants where overdosage of chemicals is mandatory due to septic or improperly treated sludge. As can be noted in Figure 1, the spraying liquor or solvent is contained in the wash trough, which is separate from the filter feed tank. Thus, there can be no dilution of the feed slurry, and cleaning operations, if necessary, may be accomplished without interfering with the actual filter operation. After leaving the washing area, the

* Now Michigan State University.

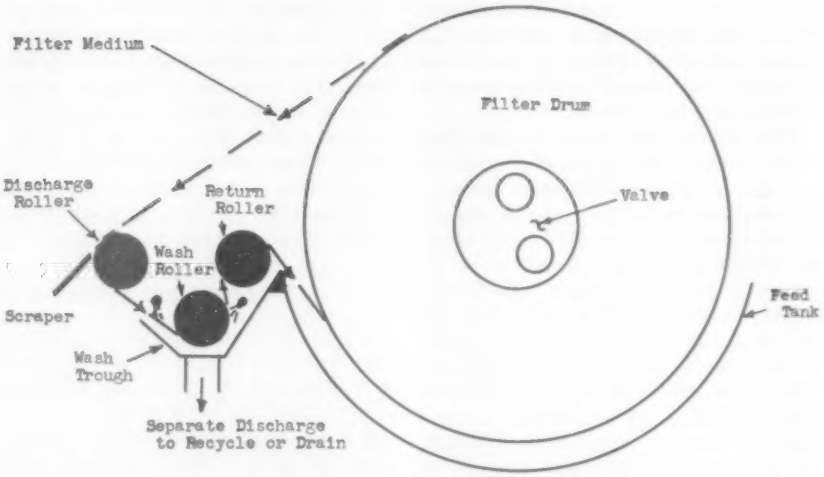


FIGURE 1.—Basic Rotobelt mechanism consisting of a drum filter, three rollers, wash sprays, a wash trough, and a medium which is removed from the drum surface and returned after the cake is discharged.

belt passes over a return roller and back onto the drum surface.

With this type of design, the first three fundamental objectives have been achieved. By using a small-diameter roller and a flexing-type medium, extremely thin cakes were continuously and cleanly discharged. This, coupled with the availability of adequate washing facilities, meant that a clean belt was constantly returned to the drum surface. Also, by discharging the cake over a roller away from the drum, no filtrate blowback was encountered.

One of the main reasons for selecting the East Lansing sewage treatment plant for the proving of this first unit was the availability of combined raw and activated sludge. It was believed that if the unit could satisfactorily handle the extremely fine particles associated with this sludge, a good chance existed for success with the filter on all types of sludge. The results of this first Rotobelt filter operation indicated that a vacuum level of 22 to 24 in. of mercury could be easily obtained at very low air requirements. The rate produced was about 5 dry psf/hr and the cake moistures averaged 80 per cent. The filtrate consistently contained about 200 to 250 ppm suspended solids. This type of operation on the East Lansing sludge is considered excellent (3). Thus, it appeared that the last three fundamental objectives had also been achieved, and the only remaining portion of the development of the unit was to verify these results on all types of sludges to insure that this new filter was not restricted in its application.

### Proving of the Filter

To be able to test the new type filter on sludges from all known methods of treatment, it was necessary to construct a portable unit that could be brought into various treatment plants throughout the country for operation on each particular type of sludge. The portable unit had to be designed so that the filter and all appurtenances were completely contained in a compact and operable state, while still of sufficient size to obtain truly representative results. To achieve these ends, a pilot plant Rotobelt having a 4-sq ft filtration

area was mounted on a trailer complete with flocculation equipment, vacuum pump, filtrate pumps, feed pump, and mix tanks. In this way, it was necessary to have only water, electricity, and a feed slurry supplied at a given plant.

The results obtained with this unit surpassed all expectations. Operation at plants presently employing vacuum filters proved that the new-type unit out-performed the plant filters in solids rate, while producing cake moistures equal to or lower than the cakes discharged from the plant filters.

One of the principal reasons for the performance of the new unit is the filter's ability to be operated at faster cycle times than those usually employed by other types of filters. As pointed out in the literature (3), if all remaining variables are constant, rate increases rapidly with decreasing cycle times. This means that the optimum operation would be at the fastest cycle time which would produce a dischargeable cake of sufficiently low moisture content. The ability to cleanly discharge a thin cake, together with the employment of high vacuum levels, which produce a low cake moisture content, allow the new filter to be operated at this fast cycle speed.

A summary of the results obtained on the trailer unit in sewage treatment plants throughout the country is given in Table I. Quite a few of the plants visited were encountering difficulties in filtering their sludge. Consequently, these plants were forced to overdose the sludge with chemicals. In every such case the chemical dosage required for filtration on the Rotobelt was reduced, some by as much as 75 per cent. These hard-to-filter

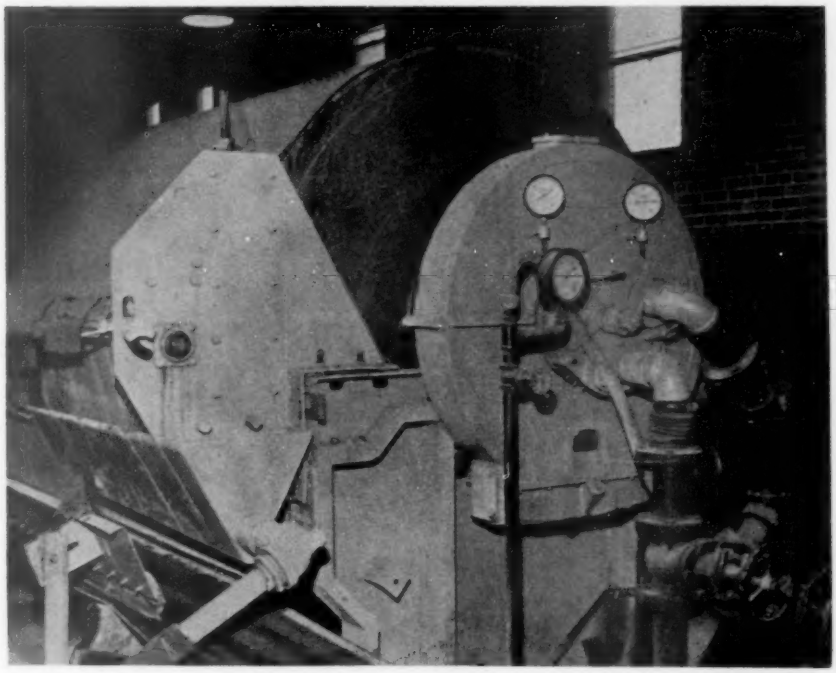

FIGURE 2.—One of two 6- by 8-ft Rotobelt filters in operation at the Fond du Lac, Wis., sewage treatment plant showing filter cake discharge—vacuum level from 22 to 25 in. Hg.

TABLE I.—Summary of Field Test Results,* Rotobelt Trailer Unit

| Type of Sludge | Rate (psf/hr) | | Cake Moisture (%) | | Chemicals (%) | |
|---|---|---|---|---|---|---|
| | Range | Avg | Range | Avg | $FeCl_3$ | Lime |
| Primary | 4.5–16 | 8.0 | 54–80 | 66 | 1.7 | 7.0 |
| Primary, digested | 4–16 | 6.0 | 64–77 | 71 | 4 | 8.5 |
| Primary, digested, elutriated | 3–20 | 6.0 | 65–73 | 70 | 2.6 | 3.6 |
| Activated, conc | 3–6 | 4.0 | 83.5–85 | 84.3 | 5.5 | 0 |
| Primary, activated | 3–11.5 | 5.0 | 71.6–87 | 79.5 | 4.1 | 4.0 |
| Primary, activated, digested | 3–10.8 | 5.0 | 72.5–79 | 75.9 | 4.0 | 9.8 |
| Primary, activated, digested, elutriated | 3–7.9 | 5.5 | 71.5–82.5 | 77.4 | 4.9 | 5.0 |

* Total number of sewage plants visited, 35.

sludges tended to raise the average cake moisture and chemical consumption while lowering the average rate, as indicated by the wide range exhibited on rate and moisture results.

However, the over-all Rotobelt results are considered good by comparison with present sludge filter performance (2). The average rates for a given sludge are much higher than the average rate for that sludge on other filtration equipment. The average cake moisture values are equivalent to the average moisture values ob-

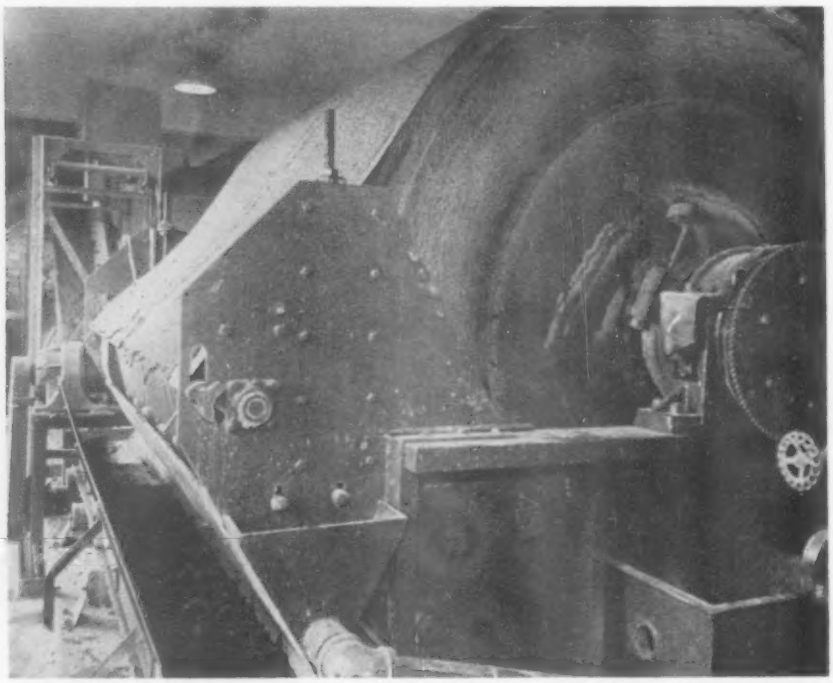

FIGURE 3.—One of two 8- by 8-ft Rotobelt filters in operation at the Ann Arbor, Mich., sewage treatment plant showing filter cake resulting from primary-activated-digested sludge from domestic sewage containing large amounts of silt.

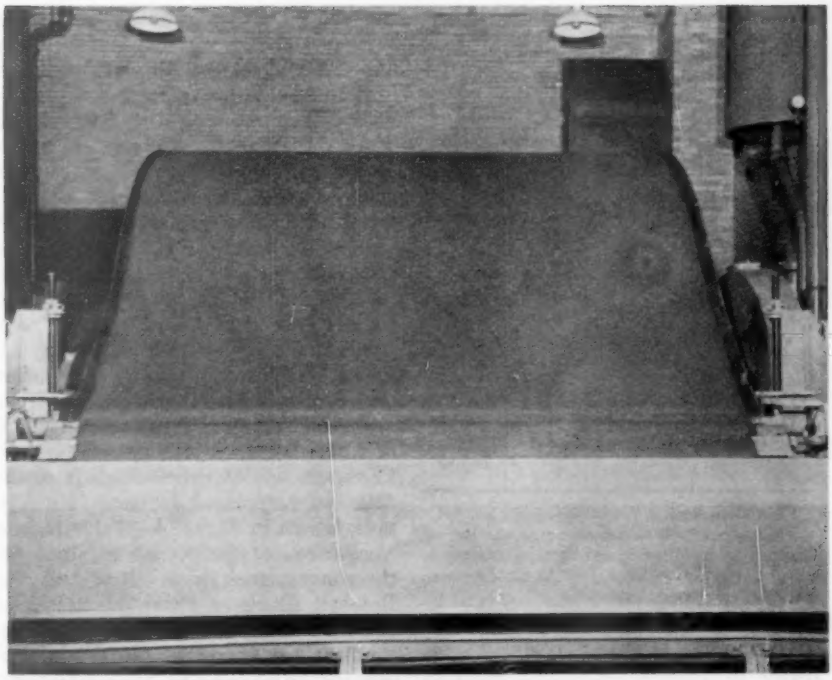

FIGURE 4.—An 8- by 8-ft Rotobelt filter in operation at the Cranston, R. I., sewage treatment plant showing smooth, even filter cake resulting from effective vacuum seal.

tained on cloth-covered drum filters employing equal vacuum levels. The average chemical dosages also appear to be equivalent or slightly lower than average dosages presently utilized on sludge vacuum filtration equipment. Therefore, in view of the fact that at least one-third of the tests were obtained on either septic, partially-digested, or extremely poor filtering sludges, the Rotobelt results were considered good enough on all types of sludges, that the design was released for use in manufacturing full-scale units.

## Full-Scale Installations

After the new-filter design had proved successful for operation on all types of sludge, several full-scale units were installed at treatment plants in various sections of the country. Three of the earliest of these units were placed in operation at Fond du Lac, Wis., Ann Arbor, Mich., and Cranston, R. I.

The first two of these plants had been forced to employ high chemical dosages due to the poor filtering characteristics of the sludges. A majority of the Fond du Lac influent contains waste from a local tannery; a difficult filtration problem is presented because of the large amount of hair and grease present. The Ann Arbor influent is almost completely domestic sludge with a high content of silt; it also is very difficult to filter. Both of these plants employ primary-activation-digestion treatment, whereas the Cranston plant follows this treatment with elutriation of the digested sludge.

A relatively short cloth medium life was experienced in all plants due to a severe blinding problem. The Fond du Lac plant prolonged the life of the

**TABLE II.—Summary of Operational Results on 6- by 8-ft Rotobelt and 6- by 8-ft Cloth-Covered Drum Filter, Fond du Lac, Wis.**

| Item | Conventional Drum | Rotobelt |
|---|---|---|
| Cycle time (min/rev) | 5.0 | 2.5–3.0 |
| Vacuum (in. Hg): | | |
| Form | 23 | 24–26 |
| Dry | 23 | 21–22 |
| Filter medium | Polyethylene | Woven wire* |
| Filtration rate (lb dry solids/hr/sq ft) | 3.0 | 4.5 |
| Cake moisture (wt %) | 69–70 | 69–70 |
| Chemical (wt %): | | |
| $FeCl_3$ | 4 | 3–4 |
| CaO | 16 | 16 |
| Filtrate clarity | —† | 100 ppm or less |

* Stainless steel.

† Filtrate clarity depends on condition of fabric used as filtering medium. If fabric is new, clarity is excellent; if fabric is worn, clarity is correspondingly poor.

cloth slightly by using frequent acid rinses to remove carbonate buildup, which resulted from the high dosage of lime employed for flocculation. The Ann Arbor plant, however, could not clean its filter medium and had to replace it approximately every week. The Cranston plant influent contains a large volume of textile wastes, which result in a thin sticky filter cake formation. Consequently, the filter cycle speed had to be quite slow to permit formation of a cake of sufficient thickness to discharge fairly well and minimize cloth blinding on the napped Dynel medium used with a string discharge mechanism on the drum filters. Due to the relative slowness of this cycle speed, filter production was lower than the design rate.

Obviously, these methods of operation were unsatisfactory to the plant operators, from both a labor and material usage standpoint. Conversion to filters based on the new design would eliminate belt replacement and at the same time lower the flocculating reagent requirement. In addition, it was hoped that the new filter would increase sludge production capacity over the present output, as all plants had to handle heavy loads. This was particularly true in the case of the Fond du Lac plant, where recent population and industrial plant expansion had increased the plant influent to a point where the present cloth-covered drum filters could not handle the entire load.

At Fond du Lac, two 6-ft diameter by 8-ft long drum filters were replaced by two 6- by 8-ft Rotobelts, one of which is shown in Figure 2; at Ann Arbor, two 8- by 8-ft drum filters were replaced by two 8- by 8-ft units, one of which is shown in Figure 3; and at Cranston, one of two 8- by 8-ft drum filters was replaced by an 8- by 8-ft unit, shown in Figure 4. Table II is a comparison of the results obtained on the conventional drum filters and the Rotobelt filters at Fond du Lac. As can be seen from this comparison, the Rotobelt has increased the productive capacity by 50 per cent, while maintaining the same low cake moisture con-

**TABLE III.—Summary of Operational Results on 8- by 8-ft Rotobelt and 8- by 8-ft Cloth-Covered Drum Filter, Ann Arbor, Mich.**

| Item | Conventional Drum | Rotobelt |
|---|---|---|
| Cycle time (min/rev) | 6.0 | 2.5 |
| Vacuum (in. Hg): | | |
| Form | 25 | 22 |
| Dry | 20–25 | 20 |
| Filter medium | Canton flannel | Woven wire* |
| Filtration rate (lb dry solids/hr/sq ft) | 2.5 | 5.0+ |
| Cake moisture (wt %) | 75–80 | 70–75 |
| Chemical (wt %): | | |
| $FeCl_3$ | 10 | 3.5 |
| CaO | 24 | 17 |
| Filtrate clarity | —† | 200 ppm or less |

* Stainless steel.

† Filtrate clarity depends on condition of fabric used as filtering medium. If fabric is new, clarity is excellent; if fabric is worn, clarity is correspondingly poor.

tent previously obtained on the cloth-covered drum filters. This increase in rate has substantially assisted the plant in keeping pace with the increased flow. Fond du Lac has reduced the ferric chloride addition slightly since the new filters were installed. Although the monetary value of this savings is not accurately known to date, it is expected to be in the neighborhood of $1,000 per year.

Comparison of the filter operation at Ann Arbor, presented in Table III, indicates that a 100 per cent increase in rate is obtained with the new filter operation. This is due to the much faster cycle time, coupled with a clean medium being returned to the drum every revolution, which permits peak filtration rates to be obtained at low cake moistures. The clean medium allows a more effective use of the vacuum and, in this case, a reduction of 5 per cent in the average cake moisture was obtained. This reduction in cake moisture content has meant the difference between operating and not operating the incinerators, as the cakes from the conventional drum filters were too wet for economic incineration.

Another important saving in the Ann Arbor plant has been the reduction in chemical requirements from 10 per cent ferric chloride and 20 per cent lime to 3 per cent ferric chloride and 15 per cent lime. In a monetary evaluation, this means that the new-type filter saves the city of Ann Arbor $101.52 per day in chemical reduction alone, or approximately $10,000 per year, in dicating a rapid write-off of the cost for the conversion.

Table IV summarizes the results obtained at Cranston. Again, it is seen that the production rate is increased by conversion to the new filter operation. In this case the rate increase is 70 per cent greater than the cloth-covered filter production. It is believed that this is primarily the result of a more effective use of the vacuum due to a continuously open medium. When operating with a semi-blinded cloth medium, the pressure drop across the cloth alone may be one-third of the total vacuum. Thus, even though the vacuum gages of both types of filters have identical readings, the cloth filter may have only two-thirds effective vacuum compared to the new type. This illustrates the advantage of being able to clean the filter medium during operation.

**TABLE IV.—Summary of Operational Results on 8- by 8-ft Rotobelt and 8- by 8-ft Cloth-Covered Drum Filter, Cranston, R. I.**

| Item | Conventional Drum | Rotobelt |
|---|---|---|
| Vacuum (in. Hg): | | |
| Form | 17–20 | 17–20 |
| Dry | 17–20 | 17–20 |
| Filter medium | Dacron with nap[a] | Woven wire[b] |
| Filtration Rate (lb dry solids/ hr/sq ft) | 3.3[c] | 5.3–5.9[d] |
| Cake moisture (wt %) | 80 | 80 |
| Chemical (wt %): | | |
| $FeCl_3$ | 5–6 | 5–6 |
| CaO | — | — |
| Filtrate clarity | —[e] | 100–300 ppm |

[a] String discharge.
[b] Stainless steel.
[c] 25,000 lb in 7.6 hr.
[d] 40,000–45,000 lb in 7.6 hr.
[e] Filtrate clarity depends on condition of fabric used as filtering medium. If fabric is new, clarity is excellent; if fabric is worn, clarity is correspondingly poor.

At present, 22 of the new-type filters have been installed or are in the process of being built. Eighteen of these units are in sewage applications, indicating the rapid acceptance of this type of filter in the past two years.

## Summary

In the field of waste treatment there has been a need for filtration equipment which would eliminate blinding problems and reduce operational costs while offering high productive capacity and low cake moistures. The Rotobelt filter has proved through extensive

tests to be capable of this level of operation. In filtering sludge at various treatment plants in all sections of the country, a trailer-mounted unit proved conclusively that it could be operated on all types of sewage sludge while out-performing conventional filtration equipment.

Full-scale comparisons between the new-type units and cloth-covered drum filters demonstrated the economic values of these units with the increase of 50 to 100 per cent in productive capacity, the reduction in cake moisture, and the reduction in chemical requirements to the extent that one plant was able to save $10,000 per year in chemical costs and eliminate belt costs and replacement.

### Acknowledgments

Appreciation is expressed to C. W. Bogenhagen, superintendent of the Fond du Lac sewage treatment plant; C. P. Witcher, superintendent of the Ann Arbor sewage treatment plant; and W. C. Anderson, superintendent of the Cranston sewage treatment plant, for the complete cooperation extended during the evaluation of the Rotobelt filter.

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## M.O.P. No. 6

The Federation Manual of Practice No. 6, "Units of Expression for Wastes and Waste Treatment," is now off the press and available from the Federation office at 25¢ to members and 50¢ to non-members. The manual was published (THIS JOURNAL, **30**, 5, 709, May 1958) to give the JOURNAL readers the opportunity to use and evaluate the units.

The Federation is offering these manuals since many will want to have at hand individual copies for reference. The manual is jacketed with the standard 6¾- by 10-in. orange cover, and is punched for inclusion in the three-ring FSIWA Manuals of Practice binder.

The Subcommittee on Units of Expression of the FSIWA Committee on Sewage and Industrial Wastes Practice has prepared this manual in an effort to encourage some uniformity in technical expression in the waste-water field. Further comments by readers and users are welcomed.

# SPIRAL CONTACT AERATION IN BIOLOGICAL TREATMENT *

By Frederick G. Nelson

*Director, Sanitary Technical Division, Dorr-Oliver, Inc., Stamford, Conn.*

The Spirovortex system † is a biological method for the treatment of domestic sewage and industrial wastes. In principle it resembles the activated sludge process, but it differs in many essential respects. Experience to date has indicated that operation of the system is not as sensitive as for the activated sludge process, but rather it has the same ability as trickling filters to handle fluctuating loads. This makes the system particularly adaptable for partial treatment, or for small- to medium-size plants where highly-trained technical supervision is not available.

## General Description

Biological oxidation is accomplished in separate aeration and contact units. Contact takes place in one or more circular detention basins designed in such a manner as to create a spiraling action of the tank contents. Flow from the primary clarifier, as well as the recycled flow from the aeration unit, enters the tank tangentially, causing a swirling motion. The outlet to the recirculation pumps is through a vortex deflector at the center of the tank. The deflector serves to prevent excessive vortex draw-down with resulting loss of head.

Aeration is by means of an external aerating device; so far, a special high-rate filter or an aeration deck has been used commercially, but other methods have been tried experimentally. Regardless of the type of aeration used, flow is recycled from the contact tank to the aerating device and back to the contact tank a sufficient number of times to effect the desired degree of treatment.

Other units included in the system consist of primary clarification, recirculation pumps, and secondary clarification. Primary and secondary clarification units are of conventional design, but for economic reasons the recirculation pumps must be of a type having high efficiency at low head and high capacity.

## History

The process was developed in California and initial tests were made at the Turlock and Monterey sewage treatment plants in 1951 and 1952. At Monterey the system treated a small portion of the clarified domestic sewage to produce reclaimed water for lawn sprinkling and other uses where a nonpotable water would suffice. The Turlock installation was for the purpose of giving partial treatment to a highly concentrated industrial sewage consisting primarily of wastes from poultry-slaughtering and potato-processing plants. At these plants it was shown that the system was capable of handling a wide range of sewage treatment problems.

The Hayward, Calif., plant was put into operation early in 1953 and extensive studies were made during that summer. In addition to domestic sewage, the plant treats large quantities

* Presented at 1957 Spring Meeting, New York Sewage and Industrial Wastes Assn.; Lake Placid, N. Y.; June 17, 1957, under the title "The Operating Principles of the Spirovortex System."

† Patented process, Dorr-Oliver, Inc., Stamford, Conn.

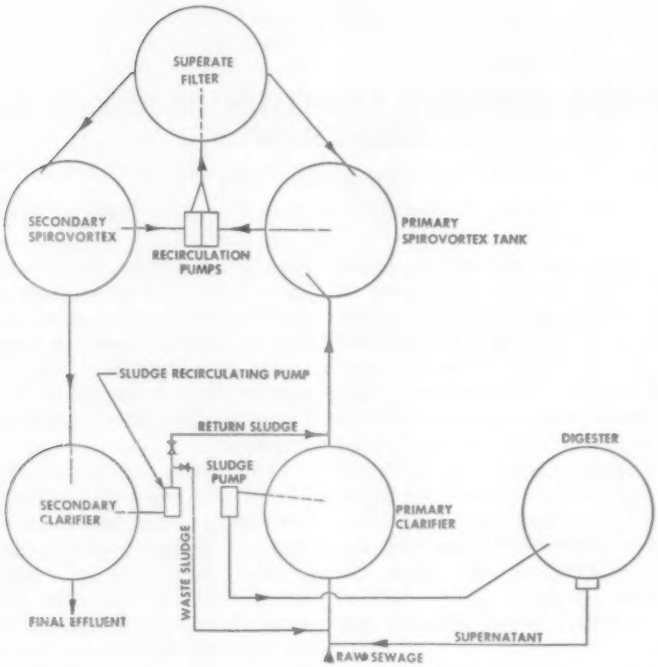



**FIGURE 1.—General flowsheet of spiral contact aeration process, including special high-rate trickling filter.**

of industrial wastes from fruit and vegetable processing plants. The load was greatly in excess of the design capacity but, even when it was no longer possible to maintain aerobic conditions in the contact tanks, the suspended solids and BOD reductions were unusually high.

Data from a test period at Pismo Beach are included herein.

## Flowsheets

Figure 1 shows a general flowsheet using primary and secondary clarifiers, two aeration contact tanks, two recirculation pumps, and one specially designed high-rate trickling filter.* The flowsheet is essentially that used at the Pismo Beach plant.

Raw sewage enters the primary clarifier, from which the settled effluent goes to the primary contact tank, entering tangentially at the periphery. Where two contact tanks are used, as shown in Figure 1, a common channel carries the underflow from both the primary and secondary units, permitting the water level to equalize. Either one or both of the recirculation pumps are operated, depending on the load on the plant. Effluent from the single high-rate filter divides between the two contact tanks.

Sludge from the secondary clarifier is handled in the same manner as activated sludge, where a portion is returned to the system and the excess wastes to the primary clarifier influent for thickening with the raw sludge. For plants having a separate sludge thickener, the waste secondary sludge is mixed with primary sludge and carried directly to the thickener.

* Patented under the name "Superate" by Dorr-Oliver, Inc., Stamford, Conn.

*High-Rate Trickling Filter*

On the present basis of design, the filter is designed for a recirculation ratio of between 20 and 25 parts recirculated to 1 part of sewage to be treated. The dosing rate is figured at 450 mgd/acre maximum with a rock depth of 1 ft. These values are considered conservative, but are recommended until further operating data are available.

To avoid the possibility of filter clogging, the recommended effective size of filter media has been 4 to 5 in. However, experience may show that smaller stone can be used without the probability of clogging occurring. Filter underdrainage must be ample to permit quick get-away of the water and provide for free passage of air to the filter media.

The distributor is of special design to handle the extremely high rates of flow. Typical computations show 20- to 60-ft diameter distributors handling flows of from 1,750 to 17,500 gpm, with minimum rates of one-fourth the maximum. Distribution jets are placed on the leading side as well as the following side of the arms, not only to increase the efficiency of distribution but also for the obvious purpose of preventing the distributor from reaching a rotary speed where it would damage itself.

*Recirculation Pumps*

Propeller pumps of either the wet- or dry-pit type are recommended because of their relatively high efficiency at low heads. Normally, with a 1-ft filter depth, the total dynamic head will be about 5 to 7 ft, depending on the size of the plant. The dry-pit type is preferred because it gives a cleaner installation and requires less space, but it does have the dis-

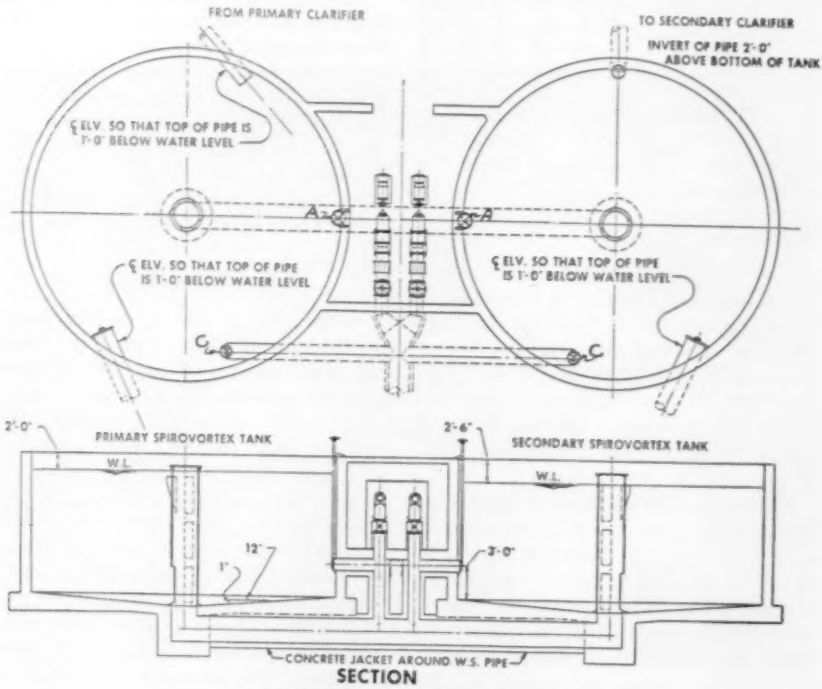
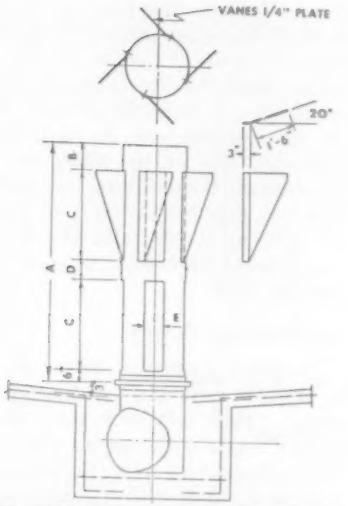



**FIGURE 2.—Typical tank layout.**




| SIDE WATER DEPTH | DIAM. VORTEX DEFLECTOR | LETTERED DIMENSIONS | | | | |
|---|---|---|---|---|---|---|
| | | A | B | C | D | E |
| 6' | 24" | 7'-9" | 1'-0" | 2'-9" | 9" | 0'-6" |
| 8' | 30" | 9'-9" | 1'-3" | 3'-6" | 1'-0" | 0'-9" |
| | 36" | 9'-9" | 1'-3" | 3'-6" | 1'-0" | 0'-10" |
| | 42" | 9'-9" | 1'-0" | 3'-6" | 1'-3" | 1'-0" |
| 10' | 42" | 11'-0" | 0'-9" | 4'-0" | 2'-6" | 1'-3" |
| | 60" | 12'-0" | 0'-9" | 4'-0" | 2'-9" | 1'-6" |

FIGURE 3.—Vortex deflector.

advantage of being less accessible for maintenance.

*Spirovortex Tanks*

The capacity of the Spirovortex tanks has been based to a considerable extent on conventional activated sludge practice. Present recommended design is based on 35 lb of applied 5-day BOD per 1,000 cu ft of tank capacity. The tanks are circular in design, with the diameter about four times the side-water depth.

Figure 2 shows a typical layout of two spiral contact tanks where a single aerating device is used. It indicates the flow circulated from the center of the tanks to the aerator and returning tangentially at the tank periphery to create the spiraling action. Velocity of rotation within the tanks can be adjusted by manipulation of valves C and A; for instance, if the velocity is too high, it can be reduced by opening valve A, or if it is desired to increase the velocity, valve A is kept closed and valve C is opened.

An important feature of the tank design is the vortex deflector, as shown in Figure 3. The design is effective in decreasing short-circuiting as well as preventing loss of head from the usual vortex drawdown.

## Other Flowsheets

Variations in the foregoing flowsheet have been used, with the Florin Road and Hayward plants being examples of such changes. The flowsheet for the Florin Road plant is similar to that for the Pismo Beach plant, with the exception that a biological filter is included as a roughing filter. The plant was designed to serve a population of 12,000, for domestic wastes only.

The Hayward plant includes vacuum flotation, a primary clarifier, a single-stage biological filter, two Spirovortex tanks, two deck aerators, and a secondary clarifier. It serves an equivalent population of 160,000. A major portion of the sewage is from fruit and vegetable canneries, and the treatment is complicated because the waste is septic by the time it reaches the plant.

## Operating Data

Table I shows results of tests made at Monterey, Calif., wherein the influent was essentially primary effluent from the main domestic waste treatment plant. BOD loading per 1,000 cu ft of spiral contact volume averaged 47 lb, or 34 per cent greater than the present recommended loading of 35 lb.

Increase in dissolved oxygen per pass over the special high-rate filter was measured at 3.1 ppm. The average recirculation was 26.6 to 1, giving a total measured dissolved oxygen of 83 ppm. Comparison of this to 154 ppm of 5-day BOD removed shows 0.54 lb of measured dissolved oxygen for each

**TABLE I.—Test Results on Monterey, Calif., Spiral Contact Aeration Sewage Treatment Plant**

| Determination | Nov. 14, 1952 | Nov. 15, 1952 | Nov. 17, 1952 | Nov. 18, 1952 | Nov. 19, 1952 | Avg |
|---|---|---|---|---|---|---|
| Flow rate (gpm) | 50 | 50 | 50 | 50 | 50 | 50 |
| Mixed liquor ss (ppm) | 2,200 | 1,728 | 1,960 | 1,392 | 1,408 | 1,740 |
| Mixed liquor SVI* | 84 | 90 | 87 | 86 | 96 | 89 |
| Susp. solids (ppm): | | | | | | |
| Influent | 53 | 104 | 77 | 63 | 93 | 78 |
| Effluent | 6.5 | 8.8 | 19 | 33 | 33 | 20 |
| Removal (%) | 87.8 | 89.5 | 75.5 | 47.5 | 64.5 | 74.5 |
| BOD (ppm): | | | | | | |
| Influent | — | — | 150 | 138 | 244 | 177 |
| Effluent | — | — | 14 | 27 | 28 | 23 |
| Removal (%) | — | — | 90.6 | 80.4 | 88.5 | 86.0 |
| BOD (lb/cu ft)†: | | | | | | |
| Loading | — | — | — | — | — | 47.1 |
| Removed | — | — | — | — | — | 40.5 |

* Mohlman Sludge Index.
† Based on volume of entire system (less final).

pound of BOD removed. Additional oxygen may enter the system by entrainment in the sludge as it passes through the filter, as well as from the surface of the contact tanks.

Table II shows results from Pismo Beach. Figure 4 shows an aerial view of this installation. The flow to the plant was approximately one-half the design rate, with the BOD somewhat higher. The average increase in dissolved oxygen per pass over the filter

**FIGURE 4.—Pismo Beach, Calif., sewage treatment plant, using Spirovortex two-stage process with special high-rate filter.**

TABLE II.—Results of 1955 Tests at Pismo Beach, Calif., Sewage Treatment Plant

| Date (1955) | Flow (mgd) | Temp.* (°F) | pH* | Susp. Solids (ppm) | | | | 5-Day BOD (ppm) | | | | Final Effl. | | Mixed Liquor | | | Filter DO (ppm) | | Load‡ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Raw | Prim. | Final | Rem. (%) | Raw | Prim. | Final | Rem. (%) | $NO_2$ (ppm) | $NO_3$ (ppm) | ss (ppm) | Vol. (%) | SVI† | On | Off | |
| 8– 3 | 0.152 | 72 | 7.8 | 231 | 89 | 23 | 90.0 | 231 | 152 | 24 | 89.6 | 0.7 | 0.1 | 676 | 76 | 160 | 0.8 | 4.6 | 0.23 |
| 8– 4 | 0.156 | 72 | 7.8 | 217 | 75 | 18 | 93.8 | 244 | 141 | 18 | 92.6 | 0.35 | 0.6 | 898 | 72 | 150 | 0.6 | 4.6 | 0.16 |
| 8– 5 | 0.174 | 73 | 7.7 | 268 | 77 | 22 | 92.2 | 280 | 150 | 21 | 92.5 | 0.6 | 0.3 | 905 | 74 | 170 | 0.5 | 4.9 | 0.19 |
| 8– 6 | 0.215 | 72 | 7.5 | 295 | 86 | 28 | 90.5 | 273 | 148 | 26 | 91.1 | — | — | 1,005 | 76 | 165 | 0.6 | 4.4 | 0.21 |
| 8– 7 | 0.177 | 72 | 7.7 | 513 | 76 | 31 | 95.8 | 360 | 137 | 22 | 93.8 | — | — | 785 | 81 | 168 | 0.5 | 4.6 | 0.21 |
| 8– 8 | 0.162 | 73 | 7.7 | 326 | 83 | 22 | 93.2 | 300 | 119 | 18 | 94.0 | — | — | 601 | 80 | 141 | 0.6 | 5.0 | 0.21 |
| 8– 9 | 0.161 | 72 | 7.6 | 359 | 74 | 18 | 95.0 | 250 | 145 | 15 | 94.0 | — | — | 635 | 75 | 146 | 0.5 | 4.8 | 0.24 |
| 8–10 | 0.167 | 71 | 7.5 | 270 | 96 | 25 | 90.8 | — | 105 | 16 | — | — | — | 648 | 75 | 146 | 0.2 | 4.8 | 0.18 |
| 8–11 | 0.157 | 70 | 7.7 | 286 | 68 | 11 | 96.1 | 278 | 102 | 14 | 95.0 | — | — | 657 | 76 | 144 | 0.2 | 4.6 | 0.16 |
| 8–12 | 0.176 | 72 | 7.7 | 302 | 96 | 19 | 93.8 | 327 | 127 | 14 | 96.0 | — | — | 688 | 73 | 131 | 0.4 | 4.6 | 0.22 |
| 8–13 | 0.176 | — | 7.6 | 222 | 72 | 42 | 81.8 | 280 | 125 | 16 | 94.5 | — | — | 679 | 74 | 162 | 0.8 | 4.7 | 0.21 |
| 8–14 | 0.174 | — | 7.7 | 390 | 104 | 29 | 92.5 | 334 | 126 | 19 | 94.4 | — | — | 676 | 65 | 170 | 2.1 | 6.1 | 0.23 |
| 8–15 | 0.159 | — | 7.6 | 320 | 96 | 17 | 94.6 | — | — | — | — | — | — | 614 | 76 | 163 | 0.9 | 4.9 | — |
| 8–16 | 0.174 | — | 7.4 | 248 | 92 | 18 | 92.8 | — | — | — | — | 2.4 | 6.0 | 519 | 77 | 221 | 1.4 | 5.2 | — |

* Raw sewage.
† Mohlman Sludge Index.
‡ Pounds BOD per pound of sludge per day.

was 4.1 ppm at a recirculation ratio of 21 to 1. During the period of August 3–9, 0.7 lb of measured oxygen was introduced to the system per pound of BOD removed.

### Comparative Costs

Cost studies of this system showed capital costs to be less than either activated sludge or biofiltration, while power costs were less than for conventional activated sludge but higher than for biofiltration.

However, for a final analysis, each project should be analyzed and comparative costs determined. By such comparison it has been shown that the costs are in line with other methods of sewage treatment, even when based on present conservative design factors.

### Advantages

1. Although the system has many of the characteristics of the conventional activated sludge method, it has a distinct advantage over that method because of its ability to take shock, or overload. At Hayward and Turlock, Calif., it was shown that the sludge would settle well regardless of excessive overload, which at times was so great that it was not possible to maintain the mixed liquor in an aerobic condition.

2. Operation of the system is simple and does not require the degree of technical supervision necessary for conventional activated sludge. There are no blowers, diffusers, or air-piping to maintain, as the only mechanical units consist of the recirculation pumps and the aeration device.

3. A high degree of purification can be obtained at low capital and operating costs.

4. The plant layout is attractive and does not create odor or fly nuisance.

### Summary

There are six plants in operation and one under construction which in-

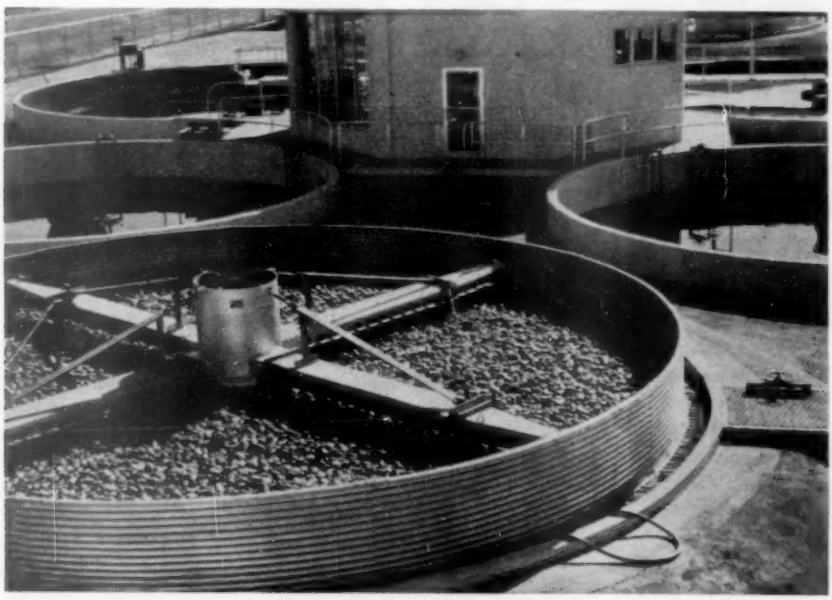


FIGURE 5.—Florin Road sewage treatment plant in Sacramento County (Calif.) has high-rate filter (foreground), two Spirovortex units (right and left), and biofiltration (rear) as a roughing unit.

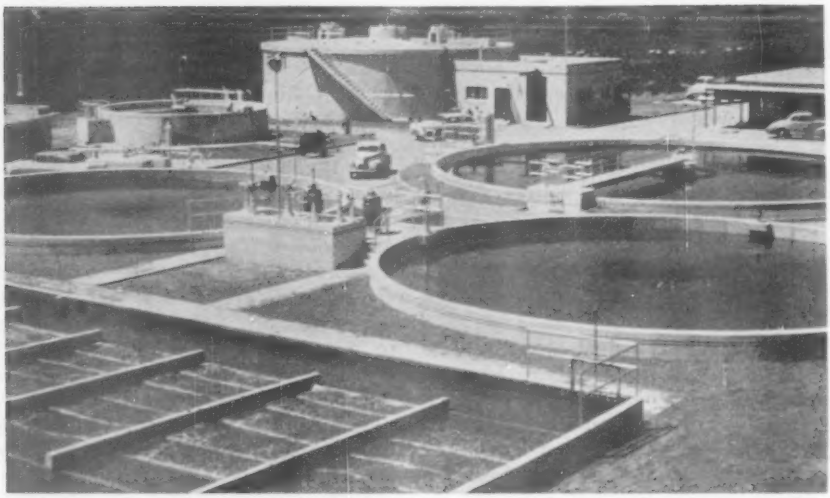


FIGURE 6.—Novato Sanitary District plant aerates by means of deck unit (foreground).

corporate the Spirovortex system. These, all in California, consist of the following:

1. Castroville Sanitation District serves 3,000 persons. This is actually a single-stage biofiltration plant, but small Spirovortex tanks were added to give more complete purification and a polished effluent.

2. Pismo Beach, already described and illustrated in Figures 1 and 2, serves a population of 4,000, treating domestic sewage only.

3. Turlock treats 60,000 population equivalent of industrial wastes only. The plant consists of vacuum flotation, Spirovortex, two deck aerators, and final clarification.

4. Hayward serves 160,000 population equivalent of combined domestic and industrial wastes. The plant includes vacuum flotation, primary clarifier, single-stage biofiltration, Spirovortex, two deck aerators, and final clarifier.

5. Florin Road Assessment District (Sacramento County) serves 12,000 population, treating domestic sewage only. It includes primary clarifier, single-stage biofiltration, Spirovortex, special high-rate filter, and secondary clarifier (Figure 5).

6. Novato Sanitary District serves 18,000 population and treats domestic sewage only. The plant (Figure 6) includes primary clarifier, Spirovortex, deck aerator, and secondary clarifier.

7. Camarillo Sanitary District will soon have a plant under construction to serve 12,000 persons. It will consist of primary clarifier, Spirovortex, special high-rate filter, and secondary clarifier.

The Spirovortex system offers a new method for treating sewage and industrial wastes. It apparently combines the best features of activated sludge and trickling filters while avoiding those most troublesome. It is claimed to operate satisfactorily under shock or overload.

# Industrial Wastes

## STATE AND INTERSTATE STANDARDS FOR INDUSTRIAL WASTES *

By Robert S. Shaw and Ernest R. Segesser

*Assistant Director and Principal Public Health Engineer, Respectively, Division of Environmental Sanitation, New Jersey State Department of Health, Trenton, N. J.*

As a basis for discussion of state and interstate regulations on discharge of industrial wastes, the experiences of New Jersey will be cited.

New Jersey has a population of 5½ million in an area of 8,000 sq mi, making it the second most densely populated state. Since there is a heavy concentration of diversified industry, the industrial waste problems are likewise many. Ninety per cent of the boundary of the State is comprised of surface waters. Almost all the intrastate waters and a very large percentage of the interstate waters are used for potable purposes, recreation, or shellfish culture. Sixty per cent of the area is potable watershed from which four million people derive their public water supply. At the present time almost any pollution of a stream causes or threatens injury to the health, comfort, or property of some inhabitants of the State.

### Fundamental Considerations

Those responsible for the administration of the stream pollution control laws of the State of New Jersey are dominated in the consideration of the industrial waste problem by four fundamental facts as follows:

1. Thriving industry is vital to the economic welfare of the State. There are certain state, county, and municipal agencies whose primary function is to foster and promote industry in the State. There is competition among counties and municipalities to attract desirable new industries. It becomes necessary, therefore, to endeavor to cooperate fully with these other state, county, and municipal agencies in order that industrial development may thrive.

2. The streams of this State are natural resources and are not to be abused by any segment of the State's population or its economy. The watercourses are the natural means of removing surface waters and the inevitable waste products from community living and industrial development. It is not the privilege, however, of any municipality or any industry to utilize the theoretical capacity of receiving waters in order to get rid of polluting material that may result in injury to others who have need of or rights to the waters of the stream.

3. There must be some semblance of uniformity in the consideration of various problems relating to stream pollution. Bigness or smallness must not be the controlling factor in the treatment of these problems.

4. The current predominant uses or desirable uses of streams as dictated largely by public opinion must be considered in establishing effluent or stream specifications.

### Legal Review

With this general summary of stream pollution control philosophy as a back-

* Presented at the 43rd Annual Meeting of the New Jersey Sewage and Industrial Wastes Assn.; Atlantic City, N. J.; Mar. 12–14, 1958.

ground, a very brief review of certain sections of some of the principal New Jersey statutes on the subject follows.

R.S. 58:10–17 requires that a permit be obtained from the State Department of Health before any factory, workshop, or place for the manufacture of materials or goods is located on any potable watershed of the State.

R.S. 58:10–1, known as the Potable Water Act, prohibits the discharge of any polluting material to any stream or to the banks of any stream comprising a potable watershed. The law is specific in naming a great many substances which are considered polluting material under the law. It is significant to note that in relation to potable watersheds this law applies to interstate as well as intrastate waters of New Jersey.

R.S. 58:10–10 prohibits the effluent from any sewage disposal system or any plant for the purification or treatment of sewage or industrial waste to be discharged into any of the potable waters of the State, which, in the opinion of the State Department of Health, is of such a character as will or may cause or threaten injury to the users of any such waters. Attention is directed in this instance to the important phrase "in the opinion of the Department."

R.S. 58:11–10 requires that detailed plans and specifications be approved by the State Department of Health before any work shall have been started on the construction of any additions or alterations to any water purification or treatment plant, sewer system, or plant for the purification or treatment of sewage or industrial waste.

R.S. 58:12–2, known as the State Sewerage Act, is the basic stream pollution control law of New Jersey. It applies to any stream in this State regardless of its use. It also applies to the interstate waters.

This last-cited law provides that if the State Department of Health finds that any of the waters of the State are being polluted in such manner as to cause or threaten injury to any of the inhabitants of the State, either in their health, comfort, or property, or that any sewage treatment works are inadequate in capacity or unit design to treat and dispose of sewage before an effluent from such works is discharged to any receiving waters, the Department shall notify in writing any person, corporation, or municipality found to be polluting said waters or owning, operating, or controlling any such inadequate sewage treatment works that the person polluting said waters must cease such polluting and make such disposition of its sewage and other polluting matter as shall be approved by the Department; and alter, add to, or improve such works in order that the sewage being received therein shall be treated and disposed of, and the effluent discharged into said waters in a manner approved by the Department. Attention is directed particularly to the words "cause or threaten injury to any of the inhabitants of this State, either in their health, comfort or property." This statute as well as R.S. 58:10–1 aforementioned has been upheld in New Jersey's highest courts.

R.S. 58:12–3 provides that no plant for the treatment of sewage or other polluting substance from which the effluent is to flow into any of the waters of this State shall be constructed or operated except under such conditions as shall be approved by the State Department of Health.

It is this law that enables the Department of Public Health to establish rules and regulations relating to the design and operation of treatment works and also effluent and stream specifications.

### Administration of Rules and Regulations

The Department of Health has rules and regulations governing the submission of designs for sewage and industrial waste treatment works. These rules and regulations specify in great detail design factors on domestic sew-

age treatment plants. No specific design criteria for industrial waste treatment plants are included due to the diversity and complexity of the subject; however, the general requirements on submission of detailed plans, specifications, and engineers' reports are applicable. Insofar as is practicable the regulations on standard treatment units apply both to industrial waste and conventional sewage treatment plants. The Department of Health accepts any reasonable proposal for the construction of an industrial waste treatment plant—with such acceptance based, in part, upon consideration of the type of waste and volume anticipated, the dilution factor of the stream, the location, and the probable effect of the treatment plant effluent upon the receiving waters.

Reasonableness is emphasized as the basis for consideration of the rules and regulations. Although these rules and regulations are not law, in a situation where the rules and regulations might be ignored, construction of proposed works can be restrained by legal process. To date, this has not been necessary, however, due to the reasonable approach of the State authorities and the productive cooperation of the municipalities and industries.

## Effluent or Stream Specifications

### *Treated Effluents*

The establishment of effluent or stream specifications in relation to the operation of a sewage or industrial waste treatment plant is a relatively new concept of control in New Jersey. It was derived originally from considerations of new and little tried sewage treatment processes. It later became more commonly employed in relation to industrial waste treatment where even less was known about the treatment processes and the probable results to be obtained.

Effluent or stream specifications, especially the former, serve as guides to treatment plant owners. They also serve as guides to State engineers in gaging the efficiency of treatment plant operation. Effluent specifications usually are preferred because of their usefulness in facilitating evaluations of treatment plant efficiency from day to day. Stream specifications on the other hand are usually somewhat clumsy and most difficult to employ, particularly in a congested area. However, a stream specification can be very effective and useful in an isolated area, especially where the dilution factor is relatively low.

Effluent specifications generally are based upon the predominant or most desirable uses of the receiving waters, dilution factors, and knowledge of the nature of the industrial waste and the proposed method of treatment.

When the Department of Health establishes a stream specification in relation to a sewage or industrial waste treatment plant, the primary basis is the use of the stream, although such other factors as those mentioned above receive consideration.

It cannot be denied that both effluent and stream specifications as applied to a particular treatment plant installation are somewhat arbitrary at times. However, they are no more arbitrary than good administrative judgment would dictate in the light of information or the lack of information available at the time. In the case of an industry anticipating the construction of waste treatment facilities, such effluent or stream specifications as are contemplated by the State are made available to the industry well in advance of the design if requested. These specifications are subject to review and possible revision as a result of conference or discussion with the interested industry. Here, again, the reasonable approach causes the State authorities to be agreeable to consider any data which an industry believes will show what constitutes a reasonable effluent or stream specification in relation to its particular waste problem. Seldom have established effluent or stream specifica-

tions affecting industrial waste treatment plant design or operation been challenged as impractical or unreasonable.

The effluent and stream specifications are not law and are not intended to be law. They are intended as a guide or yardstick, not a micrometer. They are intended primarily as an administrative tool. Such specifications usually are included as special conditions set forth in permits issued by the Department of Health for the construction and operation of waste treatment plants. However, violation of effluent or stream specifications does not constitute violation of law. In case of failure to meet such specifications, the Department of Health makes a detailed investigation and if it is determined that there exists a violation of law, not merely a failure to meet effluent or stream specifications, then law enforcement is initiated. Such an investigation could lead to an amendment of a stream or effluent specification.

*Untreated Wastes*

The effluent and stream specifications aforementioned refer to treatment plant effluents and their effects on streams. They do not refer to discharges of untreated wastes. Each discharge of untreated waste, domestic or industrial, must be evaluated in terms of the applicable law. If the law involved happens to be the Potable Water Act (R.S. 58:10–1) then the required proof is merely the discharge of the polluting material to the stream or to the banks of the stream. If the material is of a polluting nature, it probably is mentioned in that statute. If not mentioned, it probably is sufficiently similar to some waste referred to in the statute to justify action. In some situations laboratory analysis may be necessary to demonstrate that the material is of a polluting nature. If the discharge is to waters which do not flow within potable watershed areas then the basic stream pollution control law (R.S. 58:12–2) would apply. In this situation it is necessary for the Department of Health to be prepared to prove that the discharge is not only of a polluting nature but that it causes or threatens injury to inhabitants of the State either in their health, comfort, or property. Thus it is seen that an effluent specification which might have been established for one or more treatment plants in a particular area does not necessarily have any bearing upon the discharge of untreated waste to the same river.

*Interstate vs. Intrastate Waters*

There is no basic difference between the approach to these problems in interstate and intrastate waters in New Jersey. There are laws relating to the discharge of wastes into interstate waters which modify to some degree those requirements which might be established by the Department of Health. These are considerations of an interstate nature which must not be ignored. The Interstate Sanitation Commission, operating as a police agency in the New York Metropolitan area, applies basically the same philosophy in its enforcement procedures as has been outlined herein. The Interstate Commission on the Delaware River Basin, better known as Incodel, an interstate cooperating agency, also applies basically the same principles in its efforts to foster and promote interstate cooperation in stream pollution control.

## Summary

In conclusion, the primary concern of the State Department of Health in the administration of the stream pollution control laws of New Jersey is the maintenance of stream conditions which will permit their most desirable uses. Regardless of law, rules, regulations, specifications, or policies, the Department of Health recognizes that its success in stream pollution control depends upon sound administrative judgment, foresight, and integrity.

# WHEY UTILIZATION—GROWTH CONDITIONS FOR *SACCHAROMYCES FRAGILIS**

By Aaron E. Wasserman, William J. Hopkins, and Nandor Porges

*Eastern Regional Research Laboratory,† Philadelphia, Pa.*

Whey, a by-product of the cheese industry, is produced at the rate of more than 12 billion pounds annually (1), of which approximately 75 per cent is disposed of as waste. Containing 4.8 per cent lactose and 0.85 per cent protein (2)(3), the discarded whey represents a reservoir of approximately 450 million pounds of sugar and 80 million pounds of protein. Conversion of this reserve into utilizable products would relieve many plants and municipalities of a serious waste disposal problem.

Conversion of whey into yeast for the supplementation of animal diets has been considered (4)(5)(6), since such yeast contains thiamin, riboflavin, and ascorbic acid (7)(8)(9), while the protein is nutritionally similar to high-grade plant protein (5). *Saccharomyces fragilis* has been grown on whey (10), and in Germany *Torula* species have been grown in plants operating in conjunction with dairies (11). Several patents have been issued in the United States for the growth of yeast on whey, principally for their enzymes (12)(13)(14) and vitamins (7). However, large-scale production of yeast from whey has not been carried out extensively. Reductions in the production costs might make this process an attractive method for the utilization of whey.

The preliminary laboratory experiments reported herein indicate that large quantities of yeast may be produced from raw whey in 3 to 4 hr.

* Presented at the 1957 Fall Meeting, American Chemical Society; New York, N. Y.; Sept. 8–13, 1957.

† A laboratory of the Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

## Materials and Methods

*S. fragilis*, NRRL Y-1109, used previously (6) to produce solids from whey, was carried on slants of yeast-maltose agar (15). However, the actual seed for an experiment was obtained from the harvested cell paste of a previous experiment. The fermentors were glass tubes, 12 in. long and 3½ in. in diameter, closed by two aluminum plates. A strong vortex was imparted to the liquid in each fermentor by an impeller rotating at 3,000 rpm and powered by a 1/30-hp motor. Air was supplied at the rate of 2 liters per minute per fermentor through an opening in the bottom plate centered under the impeller. The whey, obtained from a local cheese manufacturer, contained 4.0 per cent lactose, approximately 0.55 per cent lactic acid, and 0.09 per cent organic nitrogen. Fermentation runs were made with 500-ml quantities of the unsterilized whey media at a temperature maintained between 28 and 30°C.

Cell counts are reported as the average of two determinations made with a hemocytometer. The limitations of the cell count method are recognized, but this procedure is useful for rapid analysis of the course of yeast cell increase.

Dry weight determinations were made by centrifuging 5 ml of the yeast-medium suspension, washing the yeast with distilled water, centrifuging again, and drying at 100°C overnight. The results are reported as net increase in dry weight.

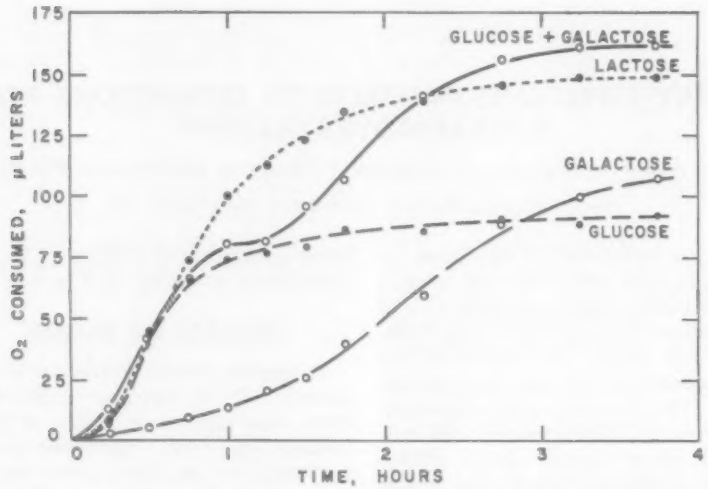



FIGURE 1.—Oxidation of sugars by *Saccharomyces fragilis* in Warburg studies.

Lactose determinations were made by the method of Stiles, Peterson, and Fred (16), and nitrogen by a modification of the Koch-McMeekin method (17). Lactic acid was determined by the Barker and Summerson method (18). Paper chromatography of sugars was conducted in butanol : acetic acid : water (4:1:5), and developed sheets were sprayed with triphenyl tetrazolium chloride reagent (19).

The data presented are representative of many experiments.

## Manometric Studies

Preliminary studies on the utilization of lactose and its component sugars by *S. fragilis* were carried out in the Warburg respirometer (Figure 1). Galactose was oxidized more slowly than glucose, and the course of oxidation appeared to be adaptive. In a mixture of the two sugars, glucose was preferentially dissimilated, followed by galactose, giving a diauxie type curve (20). With lactose as substrate, a smooth oxygen consumption curve was obtained. These data indicate that lactose is utilized directly without prior hydrolysis. Further confirmation was obtained by chromatographic analyses of the media from fermentor experiments where the only sugar observed was lactose. The absence of glucose in the media from the fermentors was also shown by negative tests with "Clinisticks," a qualitative test specific for glucose and sensitive to 0.05 per cent of the sugar (21). The data confirm the "direct fermentation" of lactose by yeast reported by other workers (15)(22)(23).

Complete oxidation to carbon dioxide and water of the 500 mg of lactose used would require 396 μl of oxygen; however, only approximately 35 per cent of this quantity of oxygen was utilized, and $CO_2$ determinations also showed the production of approximately 36 per cent of the total $CO_2$ anticipated. Therefore, 65 per cent of the carbon of lactose was available for assimilation and, under ideal conditions, a yeast yield equivalent to 65 per cent of the carbon content of the sugar could be expected.

## Fermentor Studies

### *Nitrogen and Phosphorus*

The effects of nitrogen and phosphorus additions to whey are shown in Table I. Experiments were conducted

TABLE I.—Effect of Nitrogen and Phosphorus on Yeast Yield from Whey*

| Substrate | Cell Count ($\times 10^6$/ml) | Net Dry Wt (mg/ml) | Lactose Used (mg/ml) |
|---|---|---|---|
| Whey | 1,650 | 10.64 | 4.4 |
| Whey + 1% $(NH_4)_2SO_4$ | 1,350 | 9.08 | 6.4 |
| Whey + 1% $K_2HPO_4$ | 1,480 | 12.14 | 7.2 |
| Whey + 0.25% each salt | 1,430 | 12.96 | 10.2 |
| Whey + 0.5% each salt | 2,480 | 16.14 | 19.16 |
| Whey + 1.0% each salt | 2,400 | 16.50 | 20.60 |

* Initial yeast count $500 \times 10^6$/ml; growth period 6 hr.

with the medium initially adjusted with $H_2SO_4$ to pH 4.6, seeded to contain $500 \times 10^6$ cells per ml, and allowed to progress for 6 hr. In the fermentor containing whey alone, a pH change from 4.6 to 8.0 was observed at the end of 6 hr. Addition of $(NH_4)_2SO_4$ caused little change in the yeast yield or lactose utilization, although the final pH was not as great as in the whey alone. One per cent $K_2HPO_4$ added to the whey resulted in a small increase in the yeast yield, but more important, the pH rose only to approximately 6.4 in 4 hr, then decreased again to the range of 4.5 to 5.0. The values for all measured parameters of growth increased when both salts were added to the medium, and the optimal concentration appeared to be 0.5 per cent of each salt. The pH changes were similar to those observed with $K_2HPO_4$ alone.

Complete utilization of the lactose in the 6-hr fermentation period was not attained, although considerably more sugar disappeared in the presence of 0.5 per cent quantities of both salts than in their absence, or in the presence of each salt alone.

It was noticed in these and subsequent experiments that during the early stages of growth, the dry weight cell accretion was considerably greater than could be calculated from the lactose utilization. However, when sugar disappearance was stimulated by the addition of salts and other factors, the ratio of net yield to sugar utilization was nearer to calculated amounts. Some experimental data, not reported here, indicate that if the slow lactose utilizing fermentations were allowed to proceed 24 hr instead of 6 hr, the sugar was completely utilized and the net yield of cells was low compared to the sugar disappearance.

The factors involved in the growth of the cells in the early stages of the fermentation have not been investigated at this time; however, two possible suggestions are offered to account for the apparently high yield of cells:

1. Under the conditions of the experiment, the yeast are using other carbon sources in addition, or in preference, to the lactose (lactic acid and organic nitrogen-containing compounds are readily used by the yeast, as will be reported later).

2. Some compound reacting in the non-specific reducing sugar assay for lactose may be excreted by the yeast in the early stages of growth.

### *Yeast Extract*

The effect of yeast extract on the growth of *S. fragilis* was investigated. Yeast cells grown through several transfers on the whey medium (whey + 0.5 per cent $(NH_4)_2SO_4$ + 0.5 per cent

TABLE II.—Effect of Yeast Extract on Yeast Yield from Whey*

| Substrate | Cell Count ($\times 10^6$/ml) | Net Dry Wt (mg/ml) | Lactose Used (mg/ml) |
|---|---|---|---|
| Whey medium without yeast extract | 1,400 | 14.60 | 24.0 |
| Whey medium with yeast extract | 3,070 | 21.22 | 40.0 |

* Seed yeast grown on medium minus yeast extract; initial count $500 \times 10^6$/ml; growth period 6 hr.

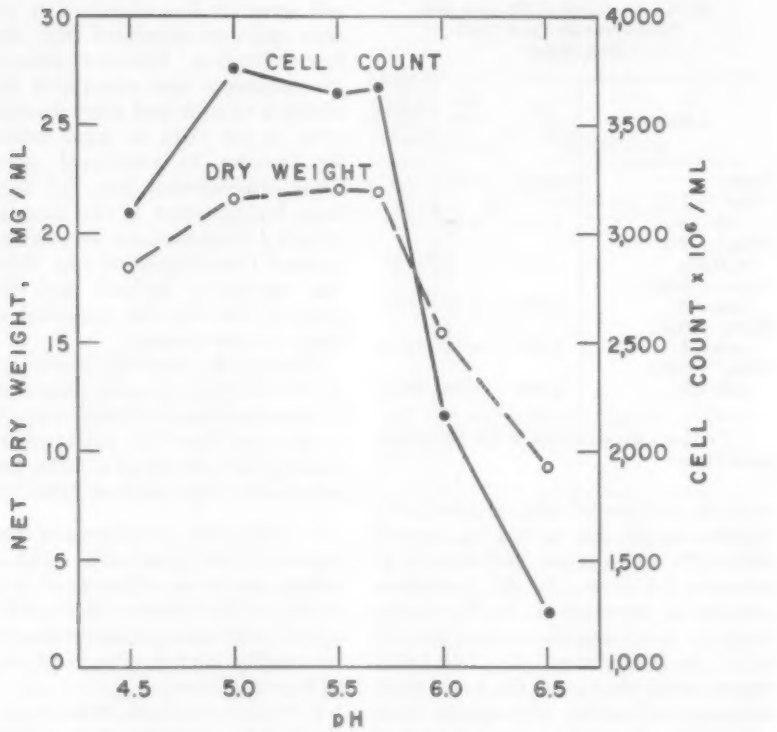



FIGURE 2.—Effect of initial pH of medium on the cell count and net dry weight of *Saccharomyces fragilis*.

$K_2HPO_4$) were divided equally between two fermentors—one containing the whey medium, and the second containing the whey medium + 0.1 per cent Difco yeast extract. The assimilation was allowed to proceed for 6 hr. A great stimulatory effect of the yeast extract was noted on the cell count, the net dry weight, and sugar utilization (Table II). Further studies on the optimal concentration of yeast extract were not carried out, although test tube growth studies indicated that 0.05 per cent yeast extract was also stimulatory to yeast growth.

The effect of the yeast extract is undoubtedly not due to the additional carbon or nitrogen, since the quantity is so small. Therefore, some vitamin or growth factor must be present. Apparently this factor is accumulated by the yeast grown in yeast extract-containing media, since it was found that transferring such yeast into whey medium with added salts, but lacking the yeast extract, resulted in a good yield for at least one transfer, before dropping back to the smaller yields obtained previously.

Although other organic extracts or concentrates have not been tested at this time, it is possible the growth factor may be found in other materials.

### *pH*

The experiments described heretofore were carried out with the medium adjusted initially to pH 4.6. It was noted that in the medium containing both salts, the pH rose to 6.0–6.5, then became more acidic again. It was decided, therefore, to investigate the effect

of the initial pH on the yield of *S. fragilis*. Media, containing whey + 0.5 per cent each of both salts + 0.1 per cent yeast extract, were adjusted to various pH levels and seeded with approximately the same amount of seed. The fermentations were allowed to proceed for 7 hr. The growth response leveled off between pH 5.0 and pH 5.7 (Figure 2) with lower yields in cell count and net dry weight on either side of these values. It was decided to adopt an initial pH of 5.7 for the whey medium. This was the pH attained on addition of 0.5 per cent $(NH_4)_2SO_4$ and 0.5 per cent $K_2HPO_4$. Furthermore, the medium seemed more stabilized at this pH, with the occurrence of only very small changes in acidity or alkalinity. Thus, maintenance of pH did not become a problem during yeast growth. It was interesting to note that at an initial pH of 6.0 and 6.5, the medium became alkaline to approximately 8.0 to 8.5 as the yeast grew, and strong ammoniacal odors were observed.

### *Inoculum Size*

The previous experiments were carried out with an inoculum size of approximately 500 million cells per ml (equivalent to about 4 mg dry wt). However, occasionally when larger inocula were used accidentally, it was noted that greater amounts of sugar were used in the 6-hr growth period. It was decided, therefore, to assess the influence of inoculum size on the yield of yeast (Table III). As the inoculum size increased from 300 million to 2.1 billion cells per ml, the time required for complete removal of the sugar dropped from over 6 hr to 3 hr. The maximum number of cells, approximately 4.5 billion, was attained in 3 to 4 hr with the larger inocula, while longer periods of time were required with the smaller quantities of seed. This also held true for the gains in net dry weights of the yeast cells, an average of about 23 mg/ml being the maximum attainable yield.

TABLE III.—Influence of Inoculum Size on Yield of Yeast

| Inoculum Size ($\times 10^6$/ml) | Cell Count ($\times 10^6$/ml) | Net Dry Wt (mg/ml) | Lactose Used (mg/ml) |
|---|---|---|---|
| 300 | 2,520 | 19.40 | 27 in 6 hr |
| 500 | 3,100 | 20.86 | 31 in 6 hr |
| 725 | 2,835 | 17.10 | 19 in 4 hr |
| | 4,140 | 25.06 | 40 in 6 hr |
| 1,165 | 3,650 | 20.38 | 30 in 4 hr |
| | 4,880 | 25.38 | 40 in 5 hr |
| 1,720 | 4,560 | 22.84 | 40 in 4 hr |
| 2,140 | 4,520 | 23.52 | 40 in 3 hr |

TABLE IV.—Yield of Yeast from Deproteinized and Raw Whey*

| Medium | Cell Count ($\times 10^6$/ml) | Net Dry Wt (mg/ml) | Lactose Used (mg/ml) |
|---|---|---|---|
| Deproteinized whey | 4,755 | 25.18 | 40 |
| Raw whey | 5,100 | 27.00 | 40 |

* Initial yeast count, 1,000 × $10^6$/ml; growth period 6 hr.

### *Heat Deproteinization*

Literature reports (3)(10)(24) have indicated that sterilization of the whey and removal of the heat-precipitated protein leads to growth of yeast superior to that attained in untreated whey. Since the yields obtained in these experiments were substantial, it was of interest to compare the effect of sterilizing the whey. Accordingly, whey at pH 4.5 was heated at 121°C for 15 min, filtered, and supplemented with the usual salts and yeast extract. The gains in net dry weight of the yeast and the sugar utilization were similar in both raw and deproteinized whey (Table IV).

### *Nitrogen Metabolism*

Since the utilization of nitrogen is an important aspect in the growth of

yeast, the availability of nitrogen in the whey medium was investigated. With whey alone, yeast growth involved the disappearance of approximately 35 per cent of the whey nitrogen, which is almost entirely in the organic fraction. Since the organic nitrogen fraction contains amino acids, peptides, and other nitrogenous compounds, as well as protein, it was of interest to determine the pattern of utilization for growth. The supernatant from an experiment using whey + 0.5 per cent salts was assayed for inorganic nitrogen and total nitrogen, the difference between the two being the organic nitrogen fraction. Protein was precipitated with 15 per cent trichloracetic acid and the supernatant analyzed for non-protein nitrogen (NPN). The results in Table V show the pattern of nitrogen utilization obtained in several experiments.

Studies reported on the nitrogen metabolism of brewer's yeast showed that the amino acids in the medium were principally deaminated and then decarboxylated (25)(26). The ammonia, although shown as being free, was probably transferred to another acceptor to form an assimilable nitrogen compound. The alcohol resulting from this reaction was considered a member of the "fusel oil" fraction. A like process probably occurred during the growth of the *S. fragilis* on whey. During the first 1 to 2 hr, corresponding to the period of highest organic nitrogen utilization, the medium has a very fruity ester odor, characteristic of amyl or iso-amyl alcohol.

**TABLE V.—Changes in Nitrogen of Supernatant Solution During Growth of Yeast on Whey + 0.5 Per Cent $(NH_4)_2SO_4$**

| Time* (hr) | Tot. N (mg/ml) | Inorg. N (mg/ml) | Org. N (mg/ml) | Prot. N (mg/ml) | NPN† (mg/ml) |
|---|---|---|---|---|---|
| 0 | 1.95 | 1.05 | 0.90 | 0.57 | 0.33 |
| 2 | 1.45 | 0.87 | 0.58 | 0.22 | 0.36 |
| 4 | 1.16 | 0.48 | 0.68 | 0.28 | 0.40 |
| 6 | 1.0 | 0.32 | 0.68 | 0.28 | 0.40 |

* Initial yeast count, $400 \times 10^6$/ml; final count, $2{,}200 \times 10^6$/ml.

† Non-protein nitrogen.

Under conditions evoking a change in the yeast metabolism (such as an initial medium pH of 6.5), the amino group, instead of being transferred to an acceptor, may be released as $NH_3$ by a mechanism like the Stickland reaction (27).

*Lactic Acid*

Approximately 0.55 per cent lactic acid was found in the whey, as a result of the cheese manufacturing process. The lactic acid was used very rapidly by the yeast and disappeared in the early stages of the growth.

## Discussion

Since economic factors are important considerations in the growth of yeast on whey, decreased processing costs would tend to increase the commercial feasibility of this operation.

The length of time required to produce the maximum net weight of yeast has been reduced to 3 to 4 hr from the 12- to 24-hr operations generally reported. Inoculation with large quantities of yeast (up to one-half the final number) leads to a rapid consumption of the whey lactose. The net increase in yeast weight in 3 to 4 hr is as great as the increased weight attained with smaller inocula in longer periods of time. The composition of the yeast cells may be different under these conditions, but data concerning this point are not yet available.

Sterilization of the whey and removal of the precipitated protein was unnecessary. In these short term experiments, little difference was observed between the yields of yeast grown on raw or deproteinized wheys. The problem of contamination was minimized by the large inoculum and the short duration of the growth period. The presence of the lactic acid bacteria in the raw whey (a residual from the cheese starter cul-

ture) may actually be a valuable adjunct in converting lactose into more readily utilized lactic acid. Graham *et al.* (4) have reported that lactose-fermenting bacterial contaminants speeded up the growth process of several yeast strains. The rapid growth of large quantities of yeast is a highly aerobic process, and the proper supply of oxygen is necessary. A study leading to calculations for the oxygen requirements of yeast growth in whey is presently under way. Some theoretical calculations have been made at this time to define the yeast obtainable from the lactose and lactic acid present in whey.

In these studies 40.0 mg lactose + 5.5 mg lactate in 1 ml whey contained 18.2 mg carbon; of the carbon 1/3 was converted to $CO_2$ = 6.06 mg carbon; therefore, 2/3 of the carbon was available for assimilation = 12.14 mg carbon.

If the dry yeast cell contains 45 per cent carbon (28), the 12.14 mg carbon should yield 27 mg yeast per ml whey. The average yeast yield obtained approximated 23 mg/ml, averaging 85 per cent of the theoretical yield.

## Summary

Whey, a by-product of cheese processing, can be used as substrate for the growth of *Saccharomyces fragilis*. The addition of 0.5 per cent $(NH_4)_2SO_4$, 0.5 per cent $K_2HPO_4$, and 0.1 per cent yeast extract are necessary for good growth. Maximum growth is attained when the medium is initially adjusted to pH 5.0 to 5.7. Seeding with a high inoculum (about $2 \times 10^9$ yeast cells/ml) reduces the length of growing period to 3 to 4 hr. The yeast grow as well in non-sterile whey as in a sterile, deproteinized whey. The nitrogen metabolism is discussed.

## Acknowledgment

Appreciation is extended to Mr. Jay Girard, Breuningers Dairies, Philadelphia, Pa., for the whey used in these studies.

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## INDUSTRIAL WASTE TREATMENT MILESTONE

In a two-day program, June 4 and 5, American Cyanamid Company dedicated a new $4½ million waste treatment plant to handle the waste from their Bound Brook, N. J., processing operations.

The first day included an air-stream pollution control seminar at which several state authorities, U. S. Public Health Service officials, university experts, and company representatives spoke on various phases of air and water pollution as related to the industrial waste problem.

Acting Governor Richard B. Stout of New Jersey and Mr. K. H. Klipstein, Executive Vice-President of American Cyanamid Company, were principal figures at the dedication ceremony on June 5.

This new facility will provide, at cost, secondary treatment for the domestic waste from the Somerset-Raritan Sewerage Authority (Somerville, Raritan, and Bridgewater) at an estimated savings to the Authority of $38,000 annually. A 20-yr contract between the industry and the Authority for this arrangement is in effect.

Ten years of research preceded the construction of the treatment facility. This research, at a cost of a million dollars, led to the actual installation, despite earlier predictions that the waste could not be treated biologically. Activated sludge is the process used to treat the complex chemical waste from 800 process lines.

Unusually long aeration (24-hr) is provided for the 20 mgd of waste in the nearly four acres of aeration tanks. Design capacity would allow for domestic waste treatment for 1¼ million people.

The example set by this undertaking is being watched with considerable interest by many in the waste-water treatment field.

# INDUSTRIAL PUBLIC RELATIONS IN POLLUTION ABATEMENT*

By W. F. Bixby

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It has been often said that "the best things in life are free." From a practical viewpoint, pure air and pure water have long been considered two of the best things in life. However, it now becomes apparent that these things can only be free if efforts are made to conserve and preserve them.

Waste disposal is not a new problem. It has existed from the first inhabitation of the earth. However, the problem of waste disposal in ancient times and until recently has not been serious because the dilution afforded by the atmosphere and natural waterways was adequate to absorb unpleasant odors and stream pollutants.

Today, this situation is changing. With the rapid growth of the world's population, and the intense industrialization in many regions of the world, disposal of waste materials takes on a completely new importance. In the United States, population has grown from 5 million in 1800 to 170 million in 1957. The iron and steel industry in this country which produced 60 thousand tons in 1810, now can manufacture 115 million tons annually. Yearly production of wood pulp has increased from a few thousand tons in 1800 to more than 22 million tons today. This industrial growth has resulted in the production of great quantities of waste products which were unknown at the beginning of the 19th century. In addition, new industries have developed; for example, the automobile industry—which was unknown before 1900—now has manufactured more than 7 million cars per year. In addition to waste products formed during their manufacture, these automobiles contribute in another way to pollution, since more than 7 million tons of exhaust gases are daily poured into our midst by the combustion of 160 million gallons of gasoline.

The advent of the atomic age has added greatly to the problems of waste elimination. Radioactive materials are dangerous in small amounts and they retain their lethal qualities for long periods of time—months, years, and decades. Unlike ordinary chemicals, they cannot be oxidized or otherwise destroyed. To make the problem more difficult, it is not yet known how deadly these materials may be. The current discussions on the dangers of A-bomb and H-bomb testing serve to emphasize this problem in its early stages. But one thing is sure. Radioactivity is dangerous and the problem of waste disposal in this field is becoming formidable.

## Industry Expenditures

During the past decade, industry has become increasingly aware of the importance of controlling waste disposal both in air and water streams. Vast amounts of money are being spent annually to correct disposal abuses which have existed in the past and to prevent new sources of pollution from occurring.

A recent survey of a number of leading companies in this country showed that 50 companies were spending a total of 18 million dollars a year on

* Presented at the 1957 Annual Meeting, Kentucky–Tennessee Industrial Wastes and Sewage Works Assn.; Louisville, Ky.; Sept. 23–25, 1957.

water and air pollution elimination. If this activity is typical, industry as a whole may now be spending 300 to 500 million dollars per year to prevent contamination of air and water. These figures constitute a powerful answer to the charge that industry, as a whole, does not wish to participate in the program to clean the country's atmosphere and streams.

### Outline of Action

Industry is today developing a progressive attitude toward the problem of pollution control. Most companies feel that they are an integral part of the community in which they are located, and consider rightfully that they have an important responsibility in maintaining a wholesome atmosphere for the benefit of the community. More and more of these progressive companies are using the following attitudes as a yardstick for meeting the problem of pollution.

1. Realistic attitude toward waste disposal: Industry no longer ignores or refuses to admit the waste disposal problems. Wastes are a by-product of life. They are a by-product of activity. When new chemicals are synthesized, when food products are processed, when fuel is produced, whether for domestic or industrial use, unwanted materials are obtained. It is not possible to ignore the fact that these waste materials are present. The problem, then, is to dispose of them in a way which does not affect the health and comfort of the community.

2. Use of expert advice in designing, installing, and operating pollution control equipment: With the importance that waste disposal is assuming at the present time, it is essential that an adequate staff be assigned to study a plant's wastes and make recommendations for improving the characteristics of the disposal streams. The day is rapidly passing when a single man could be assigned the responsibility of controlling plant disposal operations. There are too many chemicals about which too little is known to make a single man responsible for this problem. It requires chemists, biologists, engineers, and executive attention to develop a disposal operation adequate for the health and safety of the community. It is becoming increasingly evident that a more effective organization must be set up in many companies having a wide range of operations. In some cases, a separate department whose single responsibility is to guide and direct the disposal plan of the organization is becoming desirable.

3. Willingness to install pollution control equipment in spite of the fact that investment return is limited: This may seem to represent a change in attitude from conventional management policy for justifying new equipment. Actually it should be as easy to justify the installation of pollution control devices as it is to erect a building to house production equipment. A building protects equipment, material, and personnel. Waste disposal equipment protects personnel also—the people of the community.

4. Insistence by plant management that pollution control equipment be properly used: Obviously, the best of equipment is valueless unless it is used to give the results desired. In the past, adequate systems have been designed to control wastes but frequently operation of the equipment has not produced the intended results. Such a condition might result either from inadequate instruction of the operating personnel in the functioning of the equipment or from lack of insistence by plant management that the equipment be carefully supervised. It has generally been industry policy to focus attention on those operations vital to the production of saleable materials. Auxiliary operations—and waste control is one of these—received priority attention only when they were essen-

tial to insure production or when some other impetus directed effort to them.

5. Insistence by plant management that extreme care be employed to prevent discharge of objectionable materials: The old adage concerning the "futility of locking the door after the horse has been stolen" was never more true than in the case of pollution control. A single discharge of objectionable materials into public water supplies can do immeasurable damage. When an irate committee charges into a plant manager's office with a pollution complaint, the damage has been done. An emergency action is needed at this stage and the results are usually not too satisfying.

When such an event occurs, plant management is inevitably forced into "public relations" whether they want to be or not. Obviously this is the worst time to begin a public relations program. Such a program should be well planned and well executed to be effective.

## Value of Public Relations

What is meant by public relations? In this instance it is the mutual understanding between industry and the community of the problems of the other. And basically, public relations always exist whether this is realized or not. When an atmosphere of understanding and cooperation exists, public relations are good. When misunderstanding prevails or when either party ignores the welfare of the other, the public relations are bad.

Thus, public relations involve two parties—the industry and the community—and conscious effort is needed on the part of both to achieve a happy relationship.

## Industry Objectives

However, since an industrial company usually is more likely to produce quantities of materials capable of polluting public waters, greater effort is required on its part to present its problems fairly and to inform the community of its efforts in waste control and pollution prevention.

The objectives of the company cannot stop here, however. The citizenry of many industrial communities have varied interests; they often are not aware of the difference between safe and dangerous limits of potential pollutants; and they are subject to mass hysteria in cases of sudden emergencies. Therefore, a good public relations program on the part of the company must also include:

1. Accumulation of information on the needs, interests, and desires of the community.

2. A general program of public enlightenment so that the community may know what may be dangerous and what is not. This might well include a review of emergency procedures which might be taken individually under certain circumstances.

3. Close cooperation with public officials and community consultants to forestall as far as possible any chance of public hysteria in cases of emergency.

How can a company institute such a program? What is the best way to reach the public? How can a company adequately educate the public in the problems of pollution and pollution control?

## Public Relations Methods

Obviously this must be a long range program—and a continuous program. A one-shot effort is not sufficient. Many people would not hear the message. Others would hear but would be disinterested.

### *Teachers*

Every teacher knows that learning is accomplished by repetition—the more repetition the better. This is what any good public relations pro-

gram should employ—repetition, endless repetition.

The sooner a citizen begins his education on pollution control the sooner he will appreciate the problems involved and the sooner he will develop that understanding which will culminate in good public relations. Therefore, the beginning of the story should be with the youth of the community—in the schools—through the teachers.

Present day schools include courses in science, biology, chemistry, physics, natural resources, and economics. This is the real opportunity. The chemistry teacher can explain that in the manufacture of chemical "X," certain raw materials are used. During the chemical reaction certain by-products are formed which are unwanted but they exist, nevertheless. What does industry do with these by-products? There is a disposal problem here. Perhaps they are soluble in water and could conveniently be eliminated by discard into the local river, provided certain requirements are met. It may be necessary for special procedures to be taken to destroy toxic and objectionable constituents. If this is done satisfactorily, it may be possible for the remaining substances to be diluted by the stream with no harmful effects. Explanation may be made of the problems which may exist with taste and odor producing materials and the precautions which are taken to eliminate or destroy these materials.

At this point the teacher can explain what has happened in the past as a result of unusual weather conditions—drought for example. It may be emphasized that low river flows, due to lack of rain, must necessarily increase the concentration of dissolved ingredients in the stream so that it is less able to absorb additional components. It may be pointed out that under severe conditions the river has looked bad, smelled bad, or tasted bad. Then it may be shown that industry is helping to prevent such conditions by impounding wastes during dry months and discarding during high river flow. It may further be emphasized that certain operations are being curtailed or suspended during critical conditions to avoid spoiling the river under such circumstances.

If a boy hears such a story in his grammar school science class, and in his high school chemistry class, then perhaps visits a manufacturing plant during a school inspection trip where he sees effluent disposal measures, then perhaps sees an exhibit at a school open house—he has been exposed to the problem of waste disposal several times during his schooling. This has been part of his routine education—it has not been a special course and it has not been presented in an emotional atmosphere—and consequently, it has become part of his general knowledge—part of his understanding of the prevailing industrial civilization.

This means that when he has graduated into community activities, when he is a village councilman or a union leader, he will understand the problems of waste disposal and pollution control. This does not mean, of course, that he will condone pollution, but he will realize the complications of pollution control, and at least the industrial plant will be able to explain its problems and its control measures and obtain a sympathetic hearing.

In all public relations the object is to reach the greatest number of people with the story. The teachers represent an important medium of transmission. But other groups are also effective. Those who influence others are the important media.

### *Press*

The power of the press is fully recognized in public relations. In its broad sense "press" also includes should become acquainted with its press outlets and let them become acquainted with the plant.

It is often effective to invite the press into the plant to show them the facilities and to tell them what is being done in waste control and pollution prevention. Then a common understanding may be reached as to the efforts being made to protect the health and welfare of the community.

*Governmental Contacts*

Good contacts with the town or city council can be an effective means of establishing good public relations. If the councilmen are kept informed of the problems of the plant and what it is doing to take care of wastes, they will be forearmed when some enraged citizen enters a meeting with a real or suspected complaint. A voluble resident can often make quite an impression in a council meeting and unless the council knows the plant side of the story beforehand, considerable distrust and resentment can be developed before corrective action can be taken.

*Participation in Community Affairs*

Many companies encourage participation in community affairs for the purpose of promoting good public relations. This is an excellent attitude as it provides a means of obtaining information on the desires and feelings of the community as well as serving as a way of presenting the problems and efforts of the company to the community. If a company employee happens to be serving on a village planning commission or on a building codes committee, he has an excellent opportunity to become acquainted with the village engineer, the town clerk, and members of the town council. Civic-minded personnel engaged in community service, if they are well-informed, can often answer honest questions accurately and quickly, thus avoiding the growth of rumors and suspicions which might otherwise ultimately grow into issues in relations with the community.

It should be kept in mind also that the members of the town council are not permanent members. They are elected for relatively short terms and thus the complexion of the council is constantly changing. It is important to keep them up to date. Many times the industry is a vital item in community welfare. Members of the community are employees of the plant. Often it is effective public relations to bring the community residents into the plant for an inspection trip. The quick, superficial tour should be avoided. These people should be given a real explanation of what the plant does—they should be shown how the plant handles by-products and what is being done to keep wastes under control. It is important to discuss future plans, both immediate and long range, so that they may answer questions as they arise regarding intentions of the plant management.

*Adjustment of Complaints*

One of the most effective ways to encourage an atmosphere of trust and respect between the citizens of the community and the industrial plant is a willingness on the part of the plant management to investigate complaints quickly and honestly. An example of the way some complaints can be handled is cited here. An annoyed resident called the manager of a chemical plant and claimed that she could not sleep because of the terrible odor coming from this plant. Since this was a company in the rubber business she knew it was at fault because it smelled like burning rubber. Actually this statement convinced the management that the plant in question was not responsible, for this was solely a chemical plant operation; no rubber was handled at the site.

But rather than argue with the lady, the manager merely told her he did not think his plant was to blame but

that he would send someone over immediately to drive around with her to find the source of the fumes. A plant representative met the complainant a short time later and they drove completely around the plant and could find no objectionable odors. Then they drove up and down some of the other streets of the village until they finally came to the source of the trouble. Someone was burning some rubbish which obviously contained scrap rubber.

This search satisfied the complainant. It did so much more effectively than any promise to look into the matter the next day. It was immeasurably better than trying to explain that the plant could not be to blame because they did not handle any rubber at this site.

However, the search did more than merely satisfy a complainant. It proved to at least one person that the company was not trying to hide something; it proved that the plant management felt its responsibility to the community and was willing to exert itself to search out and correct sources of complaints.

While this incident is related to air pollution the same principle is applicable to liquid and solid wastes. An objective and cooperative attitude and a willingness to search out sources of complaints and correct them are powerful elements in developing good public relations.

## Summary

Developing good public relations must be a positive, progressive, and continuing program. Just as a research expert uses his negative results to direct his future investigations, so in public relations a more effective program can be prepared by knowing what not to do.

First, do not ignore the problem of pollution. Closing one's eyes to danger does not make it go away. Ignoring pollution does not correct it. To develop poor public relations in a hurry, just do nothing when the people of the community can see a colored discharge coming out of the plant site, when they can smell unpleasant fumes from the sewer outlet, or when they see dead fish on the banks below the plant.

Second, do not belittle the effects of pollution. The mere fact that a plant discharge looks bad, smells bad, or causes dead fish, condemns it as a source of pollution. The ideal for any plant is that the discharge from the plant site should look and smell good. But if this is not true, do not try to tell people it is not so bad.

Third, do not try to persuade people that pollution is an unavoidable component of industry. Many industries are polluting less today than they did a decade ago. Effective waste treatment devices have been installed and real recovery processes have been put into operation. Frequently, the value of the by-products recovered has been sufficient to justify the capital expenditure. Basically, the trend today is toward less and less pollution and this in itself belies any statement that industry and pollution are inseparable. This is possible for wastes, but not for pollution.

Fourth, do not try to shift the blame to someone else. In the first place this is a difficult task. Chemical and biological tests ultimately can trace the blame to the offending sewer. More important, an attempt to shift the blame usually offends two groups. First, it offends the industrial neighbors of the plant, because shifting the blame focuses public attention on them and they will offer no thanks for such action. Second, it offends the public —for they do not relish such treatment.

Fifth, do not engage in wishful thinking. If a plant has a pollution problem, it should be recognized for what it is. Accept pollution as a pollu-

tion problem and then do something about it.

In discussing public relations one fact should be crystal clear. Public relations is not a method or procedure for covering up or for avoiding the necessity for working on pollution control. Public relations, as far as industry is concerned, can only be used to transmit the true facts to the public. It can present the problems and the efforts of the industrial plant. The best start—in fact the only start—for a good public relations program is a desire on the part of the plant management to participate in a logical and progressive program of pollution control. Public relations can then portray this progressive attitude to the community.

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## MEETINGS OF INTEREST

### 1958

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|---|---|
| Aug. 27 | **State Chamber of Commerce Water Supply Conference,** Sherman Hotel, Chicago, Ill. J. G. Ronchetto, Illinois State Chamber of Commerce, 20 North Wacker Drive, Chicago 6, Ill. |
| Sept. 1–13 | **2nd International Conference on Peaceful Uses of Atomic Energy,** Geneva, Switzerland. |
| Sept. 7–12 | **American Chemical Society,** Chicago, Ill. R. M. Warren, American Chemical Society, 1155 16th St., N. W., Washington, D. C. |
| Sept. 13–18 | **American Chemical Society,** Atlantic City, N. J. R. M. Warren, American Chemical Society, 1155 16th St., N. W., Washington, D. C. |
| Sept. 15–19 | **Instrument Society of America,** Automation Conference and Exhibit, Philadelphia, Pa. Fred. J. Tabery, Conference and Exhibit Manager, 3443 South Hill St., Los Angeles, Calif. |
| Sept. 15–19 | **Sewage Works Course,** Extension Conference Center, Pennsylvania State University, University Park, Pa. |
| Sept. 28–Oct. 1 | **American Public Works Association,** Muehlebach Hotel, Kansas City, Mo. Donald F. Herrick, Executive Secretary, American Public Works Association, 1313 East 60th St., Chicago 37, Ill. |
| Oct. 20–24 | **National Safety Congress and Exposition,** Conrad Hilton Hotel, Chicago, Ill. R. L. Forney, Secretary, National Safety Council, 425 N. Michigan Ave., Chicago 11, Ill. |
| Oct. 27–31 | **American Public Health Association,** Kiel Auditorium, St. Louis, Mo. Dr. Berwyn F. Mattison, Executive Secretary, 1790 Broadway, New York 19, N. Y. |

# Stream Pollution

## SIGNIFICANCE OF MINERALS IN WASTE-WATER*

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An investigation was made of the quality of waste-water existing at various sewage systems throughout the United States. By means of field studies, and a letter survey, data have been collected on the mineral quality of waste-water at more than 25 representative sewage systems.

Specific phases of the waste-water quality study were concerned with:

1. An investigation of the mineralization extent in both the original water supply and the resulting sewage effluent.
2. An evaluation and comparison of the mineral quality of these waste-waters with known water quality standards for irrigation and potable water usage.
3. A detailed study of the organic, bacterial, and mineral qualities of the Los Angeles City waste-water prior to and following complete treatment.
4. A summary review of the feasibility of reclaiming waste-water for agricultural, industrial, and recreational use, and ground water recharge.
5. An analysis of methods of conserving water quality by proper planning and suitable controls.

Water quality describes in part the mineral, bacteriological, and organic characteristics of a water. Such undesirable water constituents as large concentrations of organic matter, bacteria, odor, and color can be removed at relatively reasonable costs by known treatment processes. However, the mineral composition of a water consisting of soluble inorganic compounds is usually more costly to remove. Water quality is thus closely dependent on the basic inorganic mineral composition.

Table I describes the recommended concentrations of various soluble and suspended matter encountered in water. These limiting concentrations are derived from the U. S. Public Health Service (1) and the U. S. Department of Agriculture (2). Excessive concentrations of certain minerals may result in deleterious effects on vegetation growth, and restrict water use for industrial or potable applications. Hence, it is of the utmost importance to protect the basic mineral quality of a water source so that water can be used to maximum advantage.

### General Introduction

Rivers, lakes, and ground waters are accepted as the water sources for domestic and other users, yet upstream cities commonly dispose of their waste-waters directly into these water sources. Therefore, downstream water users are employing the diluted waste-waters of the upstream suppliers. Septic tanks and cesspools that discharge waste-water into the underground aquifers are also suppliers of incidental waste-water for reuse. It is evident that the water derived from a waste-water source extends the available water resources, but it makes the user dependent on the quality of the waste-water entering the supply. This is evidenced by a large-scale planned water reclamation system in Germany (3).

In semi-arid areas, such as the

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**TABLE I.—Evaluation of Hyperion Waste-Water Quality**

| Analysis | Suggested Limiting Std. | | Local Water* | Hyperion Plant | |
|---|---|---|---|---|---|
| | USPHS Drinking Water | USDA Irrig. Water | | Raw Sewage | Treated Sewage† |
| Bacterial: | | | | | |
| Coliform (no./ml) | 50 | 100 | 0.45− | $1\times10^6$+ | 0.45− |
| Organic: | | | | | |
| BOD (ppm) | 0.5 | — | — | 250 | 1 |
| Ether solubles (ppm) | 2 | 5 | — | 38 | 1 |
| Volatile acids (ppm) | — | — | — | — | 7 |
| Physical: | | | | | |
| pH | 6.8–8.0 | 6.0–9.0 | 8.4 | — | 7.9 |
| Turbidity (ppm) | 20 | — | 1 | High | 6.7 |
| Color (ppm) | 30 | — | — | — | 5 |
| Susp. solids (ppm) | 100 | — | — | High | 12 |
| Floating solids | None | — | None | High | None |
| Odor | None | Noxious | None | High | None |
| Taste | None | — | None | High | None |
| Temperature (°F) | 60 | — | 63 | Var. | Var. |
| Chemical: | | | | | |
| Total diss. sol. (ppm) | 1,000 | 1,500 | 636 | 869 | 1,074 |
| Chlorides (ppm) | 250 | 500 | 77 | 230 | 239 |
| Fluorides (ppm) | 1.5 | — | 0.3 | 0.7 | 0.7 |
| Toxic metals (ppm) | 0.05 | — | None | Trace | None |
| Phenols (ppm) | 0.001 | — | — | Var. | 0.0005 |
| Boron (ppm) | — | 1 to 3 | 0.16 | 0.4 | 0.9 |
| Hardness, $CaCO_3$ (ppm) | 250 | — | 306 | 269 | 315 |
| Nitrates, as $NO_3$ (ppm) | 20 | — | — | 0.3 | 15 |
| Na (%) | — | 75 | 78 | 61 | 61 |
| Detergents, ABS (ppm) | — | — | — | 10 | 1.1 |

* Average analyses, 1952–4, Metropolitan Water District of California, filtered water.
† Following high-rate activated sludge and intermittent sand filtration treatment.

southwest United States, planned reuse of waste-waters is increasing the available water supply for many communities and industries.

The costs of waste-water reclamation can be made attractive by (a) employing simple low-cost methods of waste-water stabilization and (b) planning the integration of the waste-water reuse program into an over-all disposal, conservation, and water supply plan. Such over-all planning permits segregation and elimination of highly mineralized effluents.

Large urban areas are encountering increasingly critical water shortages, and the cost of importing foreign waters grows directly with the import distance of the supply. It would appear logical to dilute and reuse an existing waste-water with other water from an imported source, as does a downstream user on a river. Many communities treat their waste-waters at considerable expense only to abandon the reclaimable product. It is estimated that in the United States there are some three billion or more gallons of waste-water produced each day which can be directly employed as a "water source." An additional benefit of direct water reclamation is the alleviation of pollution and contamination of the remaining potable waters.

## Water Quality Data

The water quality data are summarized in Tables I, II, III, and IV; the sources of water and sewage analyses are described in Table V.

The normal mineral content increment measured as total dissolved solids

following the domestic use of a potable water varies from about 121 to 450 ppm (see Table II). The higher concentration of minerals may be attributed to such factors as the softening of a hard water by employing zeolites regenerated with common salt, or by industrial waste pollution. The lower increments represent dilution from infiltrated water or combined storm water and sanitary sewer systems. Severe industrial waste pollution is often indicated by a mineral increase in the range of 450 ppm total dissolved solids (see Table II).

Some industries have found it practical to reclaim certain of their mineral wastes at a profit. Where this is not possible, industry has accepted the burden of treating and disposing of undesirable industrial wastes in order to protect the quality of a receiving water. This practice can be used for maintaining the mineral quality of reclaimed water.

Oil brine disposal from refineries and oil fields has been responsible for gross waste-water mineralization as high as 1,700 ppm or more total dissolved solids (see Table II). The petroleum-producing industries have found that "flooding" with waste oil brines is a desirable practice in many locations for repressuring oil strata. Hence, it may be possible to use this disposal method for preventing in part the mineral degradation of waste-water by oil brines.

**TABLE II.—Water and Waste-Water Quality, Major Mineral Constituents (PPM)**

| Location and Sample* | | Ca | Mg | Na | K | $CO_3$ | $HCO_3$ | $SO_4$ | Cl | Total Diss. Sol. |
|---|---|---|---|---|---|---|---|---|---|---|
| San Francisco, Calif., Southeast plant | W | 13 | 4 | 8 | — | 0 | 54 | 8 | 8 | 72 |
| | I | 55 | 90 | 742 | — | — | 344 | 191 | 1,262 | — |
| | S | 68 | 94 | 750 | 41 | — | 398 | 199 | 1,270 | — |
| San Francisco, Calif., North Point plant | W | 13 | 4 | 8 | — | 0 | 54 | 8 | 8 | 72 |
| | I | 11 | 34 | 293 | — | — | 290 | 60 | 457 | — |
| | S | 24 | 38 | 301 | 24 | 0 | 344 | 68 | 465 | — |
| San Francisco, Calif., Richmond-Sunset plant | W | 13 | 4 | 8 | — | 0 | 54 | 8 | 8 | 72 |
| | I | −7 | 11 | 47 | — | — | 212 | 10 | 61 | — |
| | S | 6 | 15 | 55 | 14 | 0 | 266 | 18 | 69 | 470 |
| Los Angeles, Calif. | W | 31 | 8 | 45 | 4 | 0 | 151 | 53 | 23 | 262 |
| | I | 41 | 14 | 133 | 15 | — | 154 | 82 | 207 | 607 |
| | S | 72 | 22 | 178 | 19 | — | 305 | 135 | 230 | 869 |
| San Diego, Calif. | W | 60 | 24 | 77 | 5 | — | 107 | 210 | 70 | 554 |
| | I | 14 | 31 | 333 | 28 | — | 392 | −38 | 569 | 1,026 |
| | S | 74 | 55 | 410 | 33 | — | 499 | 172 | 639 | 1,580 |
| E. Bay M.U.D., Oakland, Calif. | W | 31 | 12 | 17 | 2 | — | 118 | 39 | 12 | 202 |
| | I | 3 | 19 | 263 | 38 | — | — | 89 | 420 | 1,402 |
| | S | 34 | 31 | 280 | 40 | — | — | 128 | 432 | 1,604 |
| Fresno, Calif. | W | 31 | 17 | 22 | — | 0 | 183 | 6 | 28 | 300 |
| | I | — | 1 | 41 | — | — | 100 | 11 | 22 | 121 |
| | S | 24 | 18 | 63 | — | — | 283 | 17 | 50 | 421 |
| San Bernardino, Calif. | W | 49 | 11 | — | — | — | 300 | 70 | 107 | — |
| | I | — | 6 | — | — | 7 | 92 | −32 | 462 | — |
| | S | 42 | 17 | 110 | 14 | 7 | 392 | 38 | 569 | 581 |
| Oxnard, Calif. | W | 144 | 52 | 98 | — | — | 250 | 484 | 52 | 1,098 |
| | I | 8 | 5 | 161 | — | — | — | 39 | 185 | — |
| | S | 152 | 57 | 259 | — | — | — | 523 | 237 | — |
| Fontana, Calif. | W | 16 | 6 | 16 | — | 16 | 16 | 31 | 34 | 143 |
| | I | 22 | 5 | 14 | — | — | 12 | 61 | 22 | 273 |
| | S | 38 | 10 | 30 | — | 0 | 28 | 92 | 56 | 416 |
| Oceanside, Calif. | W | 90 | 33 | 114 | 5 | — | 142 | 342 | 98 | 766 |
| | I | 26 | 8 | 134 | 12 | — | 283 | −55 | 262 | 449 |
| | S | 116 | 41 | 248 | 17 | — | 425 | 287 | 360 | 1,215 |
| Chula Vista, Calif. | W | 42 | 20 | 62 | — | — | 21 | 20 | 90 | — |
| | I | 6 | 9 | 58 | — | — | 219 | 95 | 43 | — |
| | S | 48 | 29 | 120 | 17 | — | 240 | 115 | 133 | 600 |
| Palm Springs, Calif. | W | 21 | 4 | 16 | — | 0 | 88 | 25 | 10 | — |
| | I | 14 | 6 | 51 | — | 25 | 66 | 9 | 42 | — |
| | S | 35 | 10 | 67 | — | 25 | 154 | 34 | 52 | 488 |
| Mojave, Calif. | W | 63 | 7 | 44 | — | — | 240 | 42 | 44 | 310 |
| | I | — | 10 | 60 | — | — | 222 | 38 | 36 | 400 |
| | S | 43 | 17 | 104 | 13 | — | 462 | 80 | 60 | 710 |
| Azusa, Calif. | W | 57 | 19 | 6 | — | 18 | 177 | 43 | 9 | 263 |
| | I | 109 | 63 | 68 | — | — | 78 | −21 | 51 | 305 |
| | S | 166 | 82 | 74 | 12 | 0 | 255 | 22 | 60 | 568 |

* W = water, I = increment, S = sewage.

TABLE II.—(*Continued*)

| Location and Sample* | | Ca | Mg | Na | K | $CO_3$ | $HCO_3$ | $SO_4$ | Cl | Total Diss. Sol. |
|---|---|---|---|---|---|---|---|---|---|---|
| Twentynine Palms, MTC, Calif. | W | 13 | 0.5 | 56 | — | 0.5 | 76 | 36 | 35 | 242 |
| | I | — | 0.5 | 59 | — | 1.9 | 31 | 36 | 17 | 158 |
| | S | 11 | 1 | 115 | — | 2.4 | 107 | 72 | 53 | 400 |
| Edwards Air Base, Calif. | W | 27 | 4.2 | 61 | 2 | 0 | 144 | 62 | 29 | 304 |
| | I | 9 | — | 38 | 10 | — | 235 | −3 | 32 | 279 |
| | S | 36 | 4.2 | 99 | 12 | 0 | 379 | 59 | 61 | 583 |
| Philadelphia, Pa. | W | 16 | 6 | 8 | — | — | 32 | 33 | 13 | 137 |
| | I | 16 | 12 | 65 | — | — | 129 | 120 | 47 | — |
| | S | 32 | 18 | 73 | — | — | 161 | 153 | 60 | — |
| Las Vegas, Nev. | W | 120 | 23 | — | — | — | — | 58 | 6 | — |
| | I | 176 | 52 | — | — | — | — | 377 | 122 | — |
| | S | 296 | 75 | — | — | — | — | 435 | 128 | 1,148 |
| Odessa, Tex. | W | 154 | 12 | — | — | — | — | — | 160 | 895 |
| | I | 12 | 1 | — | — | — | — | — | 69 | 495 |
| | S | 166 | 13 | — | — | — | — | — | 229 | 1,380 |
| Washington, D. C. | W | 32 | 7 | — | — | 4 | 72 | 37 | 8 | 175 |
| | I | — | 1 | — | — | — | 12 | 10 | 22 | 187 |
| | S | 24 | 8 | 27 | 8 | — | 84 | 47 | 30 | 362 |
| Ft. Wayne, Ind. | W | 26 | 8 | 44 | — | — | 17 | 132 | 12 | 273 |
| | I | 55 | 19 | 43 | — | — | 87 | 54 | 50 | 361 |
| | S | 81 | 27 | 87 | — | — | 104 | 186 | 62 | 634 |
| Detroit, Mich. | W | 27 | 7 | 3 | — | — | — | — | — | 122 |
| | I | — | — | — | — | — | — | — | — | 410 |
| | S | — | — | — | — | — | — | — | — | 532 |
| Baltimore, Md. | W | 17 | 4 | 3 | 3 | — | 51 | 12 | 7 | 91 |
| | I | — | — | — | — | — | — | — | 93 | 609 |
| | S | — | — | — | — | — | — | — | 100 | 700 |
| Cleveland, Ohio | W | 34 | 9 | 8 | 8 | — | 104 | 29 | 15 | 159 |
| | I | — | — | — | — | — | — | — | 72 | 204 |
| | S | — | — | — | — | — | — | — | 87 | 363 |
| Oklahoma City, Okla., North Side (Hefner water plant) | W | 38 | 14 | — | — | — | 27 | 100 | 74 | 311 |
| | I | — | — | — | — | — | — | — | 112 | 596 |
| | S | — | — | — | — | — | — | — | 186 | 907 |
| Oklahoma City, Okla., South Side (Hefner water plant) | W | 38 | 14 | — | — | — | 27 | 100 | 74 | 311 |
| | I | — | — | — | — | — | — | — | 622 | 1,714 |
| | S | — | — | — | — | — | — | — | 696 | 2,025 |
| Watsonville, Calif. | W | 38 | 14 | — | — | 27 | — | 14 | 74 | 316 |
| | I | — | — | — | — | — | — | — | 622 | — |
| | S | — | — | — | — | — | — | — | 696 | — |
| Minneapolis, Minn. | W | — | — | — | — | — | — | — | — | — |
| | I | — | — | — | — | — | — | — | — | — |
| | S | — | — | — | — | — | — | — | 58 | 586 |
| New York, N. Y. | W | — | — | — | — | — | — | — | 40 | — |
| | I | — | — | — | — | — | — | — | — | — |
| | S | — | — | — | — | — | — | — | (60–5,000) | — |

* W = water, I = increment, S = sewage.

Sea water infiltration into low-lying sewers has also caused gross waste-water mineralization. Mineralization from sea water in coastal communities ranges from 600 to more than 6,000 ppm (see Table II). An interesting example of salt water infiltration into waste-water is provided at San Francisco, Calif. Table II describes the representative analyses for the water supply and sewage effluents for the city. It will be noted that the domestic-type waste-water from the Richmond-Sunset sewage treatment plant has relatively low mineralization and little chloride content.

In contrast, the minor pollution of industrial wastes and the gross infiltration of salt water into the Southeast and the North Point treatment plants is responsible for a much higher content of chlorides, sodium, and other dissolved solids. The proportion of Na, and Cl to $SO_4$ ions is different in a salt water polluted waste effluent from that in a "normal" waste-water such as that existing at the Richmond-Sunset plant. Other ion ratios can also be used as pollution source tracers. The Na concentration increased from 26 per cent in the potable water to 37 per cent in the Richmond-Sunset plant normal domestic waste-waters, whereas the salt water polluted effluents of the Southeast and North Point plants showed an increase to about 71 per cent Na.

A second example of salt water pol-

lution exists in New York, which is surrounded by tidal waters containing from 20,000 to 30,000 ppm dissolved solids, principally sodium chloride. The chlorides in the potable city water supply range from 30 to 50 ppm. The waste waters contain a chloride content as high as 5,000 ppm, derived largely from the inflow of tidal waters by-passing through the tidal control devices in the sewer outfalls.

## Mineral Constituents

The increase in mineral constituents is given in Tables II and III. The increment silica pickup is shown in Table IV. Analysis of these data indicates that a reasonable range of mineralization for the various ions can be summarized as follows:

| Ion | Reasonable Range* (ppm) |
|---|---|
| Calcium (Ca) | 7 to 109 |
| Magnesium (Mg) | 1 to 90 |
| Sodium (Na) | 14 to 742 |
| Bicarbonates ($HCO_3$) | 12 to 392 |
| Sulfates ($SO_4$) | 10 to 191 |
| Chlorides (Cl) | 22 to 1,262 |
| Total diss. sol. (TDS) | 120 to 450 |
| Silica ($SiO_2$) | 4 to 18 |

* The available data have been critically reviewed and the reasonable values utilized.

A disproportionate increase in the saline and alkaline ion constituents in a desert area waste-water may be attributed to the infiltration of leach from the surface soils into the collection system.

**TABLE III.—Water and Waste-Water Quality Components Affecting Agriculture (PPM Where Applicable)**

| Location and Sample* | | B | $PO_4$ | N | Na (%) | Cl | Total Diss. Sol. |
|---|---|---|---|---|---|---|---|
| San Francisco, Calif., Southeast plant | W | 0.08 | — | 0 | 26 | 8 | 72 |
| | I | — | — | — | 45 | 1,262 | — |
| | S | 0.4 | — | 28 | 71 | 1,270 | — |
| San Francisco, Calif., North Point plant | W | 0.08 | — | 0 | 26 | 8 | 72 |
| | I | — | — | — | 43 | 457 | — |
| | S | — | — | — | 69 | 465 | — |
| San Francisco, Calif., Richmond-Sunset plant | W | 0.08 | — | 0 | 26 | 8 | 72 |
| | I | — | — | — | 11 | 61 | 398 |
| | S | — | — | — | 37 | 69 | 470 |
| Los Angeles, Calif. | W | 0.4 | 0 | 0 | 51 | 23 | 262 |
| | I | — | — | — | 10 | 207 | 607 |
| | S | 0.4 | 65 | 21 | 61 | 230 | 869 |
| San Diego, Calif. | W | 0.1 | — | 0.1 | 39 | 70 | 554 |
| | I | — | — | — | 27 | 569 | 1,026 |
| | S | 0.7 | — | 45 | 66 | 639 | 1,580 |
| E. Bay M.U.D., Oakland, Calif. | W | 0.07 | — | — | 22 | 12 | 202 |
| | I | — | — | — | 47 | 420 | 1,402 |
| | S | 0.04 | 40 | — | 69 | 432 | 1,604 |
| Fresno, Calif. | W | 0.04 | 0.3 | — | 23 | 28 | 300 |
| | I | — | — | — | 18 | 22 | 121 |
| | S | 0.4 | — | 17 | 41 | 50 | 421 |
| San Bernardino, Calif. | W | 0.2 | — | — | 21 | 107 | — |
| | I | — | — | — | 26 | 462 | — |
| | S | 0.4 | — | 27 | 47 | 569 | 581 |
| Oxnard, Calif. | W | — | — | — | 25 | 52 | 1,098 |
| | I | — | — | — | 20 | 185 | — |
| | S | 1.0 | 8 | 11 | 45 | 237 | — |
| Fontana, Calif. | W | — | — | — | 37 | 34 | 143 |
| | I | — | — | — | — | 22 | 273 |
| | S | — | — | — | 33 | 56 | 416 |

* W = water, I = increment, S = sewage.

TABLE III.—(*Continued*)

| Location and Sample* | | B | $PO_4$ | N | Na (%) | Cl | Total Diss. Sol. |
|---|---|---|---|---|---|---|---|
| Oceanside, Calif. | W | 0.17 | — | — | 41 | 98 | 766 |
| | I | — | — | — | 12 | 262 | 449 |
| | S | 0.66 | 32 | 40 | 53 | 360 | 1,215 |
| Chula Vista, Calif. | W | 0.1 | — | — | 42 | 90 | — |
| | I | — | — | — | 8 | 43 | — |
| | S | 0.9 | — | 15 | 50 | 133 | 600 |
| Palm Springs, Calif. | W | Trace | — | — | 33 | 10 | — |
| | I | — | — | — | 20 | 42 | — |
| | S | 0 | 3.8 | 0.5 | 53 | 52 | 488 |
| Mojave, Calif. | W | 0.4 | — | — | 30 | 24 | 310 |
| | I | — | — | — | 30 | 36 | 400 |
| | S | 0.4 | — | — | 60 | 60 | 710 |
| Azusa, Calif. | W | — | — | — | 8 | 9 | 263 |
| | I | — | — | — | 30 | 51 | 305 |
| | S | 1.0 | 26 | — | 38 | 60 | 568 |
| Twentynine Palms, Calif. | W | 0.08 | 1.6 | 2.13 | 78 | 35 | 242 |
| | I | 0.16 | 7.6 | — | 7 | 17 | 158 |
| | S | 0.24 | 9.2 | 2.13 | 85 | 52 | 400 |
| Edwards Air Base, Calif. | W | 0.2 | — | 1 | 60 | 29 | 304 |
| | I | — | — | — | 7 | 32 | 279 |
| | S | 0.4 | — | 4 | 67 | 61 | 583 |
| Philadelphia, Pa. | W | — | — | — | 21 | 13 | 137 |
| | I | — | — | — | 29 | 47 | — |
| | S | — | — | — | 50 | 60 | — |
| Washington, D. C. | W | — | — | — | — | 8 | 175 |
| | I | — | — | — | — | 22 | 187 |
| | S | — | — | — | 38 | 30 | 362 |
| Ft. Wayne, Ind. | W | — | — | — | 50 | 12 | 273 |
| | I | — | — | — | — | 50 | 361 |
| | S | — | — | — | 38 | 62 | 634 |

* W = water, I = increment, S = sewage.

It is also possible to encounter sulfate reduction in waste-water subject to an anaerobic environment. The sulfide production and sulfate splitting action is performed by anaerobic sulfur bacteria (see Table II).

## Sodium

The sodium content is important in agricultural use of reclaimed water, as high sodium concentrations may cause a reduction in soil permeability, particularly where clay soils exist. The increase in sodium for waste-waters ranges from less than 10 to more than 45 per cent (see Table III). The high percentage of sodium increase can be attributed to the infiltration of salt and brine waters or the lack of calcium and magnesium in a low-solids potable water (see Table III).

There appears to be little boron pollution (0 to 0.4 ppm mineralization)

TABLE IV.—Representative Silica Increment Pickup in Waste-Water

| Location | $SiO_2$ Pickup (ppm) |
|---|---|
| Fontana, Calif. | 10 |
| Fort Wayne, Ind. | 4 |
| Mojave, Calif. | 18 |
| Odessa, Tex. | 14 |
| Palm Springs, Calif. | 52 |
| San Francisco, Calif. | 12 |
| Twentynine Palms, Calif. | 6 |
| Washington, D. C. | 12 |
| Average | 17.3 |

in a typical sewage effluent, except where a specific industrial waste is introduced (see Table III).

### Toxic Minerals, Detergents, Phenols

A common criticism applied to reclaiming waste-waters is that deleterious minerals or toxic constituents (such as heavy metals, detergents, and taste-producing phenols) are present.

Table I indicates that a major sewage system can supply a reclaimable water meeting conventional standards applied to irrigation and potable water supplies. The proper treatment of those effluents further insures the removal of heavy metals, detergents, phenols, and other toxic constituents.

### Other Ions

Reference is made to Tables II and III for additional data on the detailed analyses of the waste-waters and their increments of mineralization.

The industrial water quality is dependent on the total dissolved solids and other described constituents. For boiler water and process water, the silica content is significant. Table IV summarizes the silica pickup for waste waters at 8 representative communities. The silica ($SiO_2$) increment, in ppm, ranges from 4 to 52 and averages 16. The major increase in silica content may be attributed to evaporative processes. No significant in-

TABLE V.—Cities Providing Water and Sewage Analyses

| City | Location of Sample | |
|---|---|---|
| | Sewage | Water |
| Azusa, Calif. | Rep. tr. filt. effl. | Rep. water system |
| Baltimore, Md. | Rep. tr. filt. effl. | Rep. water system |
| Chula Vista, Calif. | G Street tr. plant, Sept. 24, 1954 | Sweetwater Lake, July 26, 1943 |
| Cleveland, Ohio | Rep. raw sewage | Rep. water system |
| Detroit, Mich. | Rep. sewage effl. | Summary of water analysis |
| Edwards Air Force, Calif. | Grab samples of sewage effl. | Grab samples of water supply |
| Fontana, Calif. | Rep. tr. filt. effl. | Rep. water analysis |
| Fort Wayne, Ind., 1941 | Plant effl. | Rep. water analysis |
| Fresno, Calif. | Rep. raw sewage | City water supply |
| Las Vegas, Nev. | Tr. filt. plant effl. | City water supply |
| Los Angeles, Calif. | Rep. Hyperion effl. | Rep. water system |
| Mojave, Calif. | Rep. raw sewage | Rep. water system |
| Oakland, Calif. | Sewage plant effl. E.B.M.U.D. | Upper San Leandro, May 18, 1956 |
| Oceanside, Calif. | Rep. raw sewage | Rep. water system |
| Odessa, Tex. | Primary effl. | Rep. water system |
| Oklahoma City, Okla. | Raw sewage, South Side plant, 1955–6 | Potable water, Overholser plant, 1955–6 |
| Oxnard, Calif. | Sewage plant effl., 1956 | Water analysis rep. well No. 1 |
| Palm Springs, Calif. | Rep. raw sewage | Rep. water system |
| Philadelphia, Pa. | Rep. raw sewage | Rep. water analysis |
| San Bernardino, Calif. | City sewage effl. composite, Dec. 13, 1956 | City Water Dept., rep. well water |
| San Diego, Calif. | Rep. sewage effl., Div. of Water Resources, Apr. 1954 | Alvarado water plant, avg treated water, 1954 |
| San Francisco, Calif. | Richmond-Sunset plant, Div. of Water Resources, Sept. 5–6, 1956 | San Andres lines, Apr. 5, 1955 |
| Twentynine Palms, Calif. | Rep. raw sewage | Rep. water analysis |
| Washington, D. C. | Primary effl. | Composite water analysis |
| Watsonville, Calif. | Rep. raw sewage | Rep. water system |

crease in iron content was noted in the representative waste-waters.

### Waste-Water Treatment, Los Angeles

Table I describes in detail the results of reclamation studies utilizing Los Angeles City waste-water and compares its quality with a potable water supply. The waste-water was treated by means of high-rate activated sludge, intermittent sand filtration, and chlorination. The data indicate that such treatment can produce a sparkling clear, reclaimed water that meets potable drinking water standards as measured by coliform count. The reclaimed water organic content, as measured by 5-day BOD, averaged 1 ppm. The detergents, as measured by alkyl benzene sulfonate compounds, was reduced from about 10 ppm in the raw waste water to 1.1 ppm in the reclaimed water.

It was previously noted that the toxic metals and the phenol concentrations were at a minimum. The high nitrate concentration indicates that a fully-stabilized water was produced which contained fertilizer nutrients valuable in irrigation of vegetation. The Los Angeles reclaimed waters are of suitable quality for many uses. Further segregation of highly-mineralized wastes would further improve the reclaimed water chemical quality.

### Extended Sampling Periods

The Minneapolis-St. Paul Sanitary District has completed more than 18 years of routine effluent sampling for total dissolved solids and pH. The average total dissolved solids was 586 ppm; individual samples varied between 290 and 1,050 ppm. The higher concentrations probably represent the effects of variable potable water quality, as well as effluent pollution by industrial wastes. In contrast, the pH shows variation between 7.0 and 8.0, averaging 7.5.

### Evaporative Cooling

Cooling towers utilize water for a cooling medium. The dissolved solids are not evaporated and concentrate in the water system so that it is necessary to eventually blow down the waste water. Obviously, a proportionate increase in the various ions, such as Ca, Mg, Cl, B, and others, should indicate that evaporative cooling is probably responsible for waste-water mineralization.

### Examples of Water Reclamation Projects

Reclaimed water can be employed for use as an irrigation, industrial, and ground water recharge supply, but because of aesthetic considerations is not recommended for direct potable water distribution. However, in one instance, such direct reuse was authorized by a state health department and provided for treated sewage to be pumped upstream and mixed with 40 to 50 per cent diluting water entering directly into the municipal water plant.

Increased technical knowledge and improved low-cost treatment processes will enable more widespread waste-water reuse (4). The Bethlehem steel plant, Baltimore, Md., and the Kaiser steel plant, Fontana, Calif., are examples of industries that successfully reclaim waste-water for cooling tower and other process applications. Both the Los Angeles Flood Control District, in cooperation with the Hyperion plant of the City of Los Angeles, Calif., as well as the Carter Oil Company at Mattoon, Ill., have reclaimed water for recharge of underground strata through an injection well system. Many parks and golf courses, particularly in the far western U. S. recreational areas, use reclaimed water to irrigate grass and shrubs. Fresno and Bakersfield, Calif., are examples of cities that maintain farms where waste-water has been used for many years to irrigate crops, such as cotton, alfalfa, and field grasses.

## Demineralization

It would appear practical to improve the mineral quality of reclaimed waste-water by demineralization, using electrolytic membranes or zeolites. Reclamation of the relatively low dissolved solids waste water should prove to be far less costly than proposed programs for salt water demineralization.

## Conclusions

1. Mineral quality is the controlling factor in employing reclaimed waste-water for many purposes.

2. A normal sewage effluent will develop additional mineralization of 100 to 450 ppm measured as total dissolved solids.

3. Excess mineral pickup greater than 600 to as high as 5,000 ppm total dissolved solids is probably attributable to tidal water or oil brine pollution.

4. Industrial wastes may contain toxic constituents, such as boron or heavy metals; however, these wastes generally can be controlled. A common source of industrial water mineralization is the blow-down from cooling towers as well as other process units.

5. Large quantities (3 billion gpd or more) of waste-water are available in sewage systems throughout the United States.

6. Reclaimed water can be provided, in many cases, with reasonable mineral quality, suitable for irrigation of grasses and other vegetation, industrial water supply make-up, and ground water recharge. Direct use for potable purposes, although technically possible, has generally not been considered aesthetically desirable.

7. Waste-water mineral quality can be maintained by:

(a) Control of the disposal of salt water pollution derived from oil brines, tidal waters, and the regeneration of zeolite water softeners. Saline waters may be reclaimed economically for oil field repressurization.

(b) Control of industrial wastes.

8. Waste-waters can be and are commonly recycled for incidental reuse in existing surface and ground waters, because the upstream users discharge their effluents and thereby provide part of the water supply received by the downstream users.

9. Suitable low-cost waste treatment methods exist for stabilizing and removing detergents, pathogenic organisms, and other undesirable organic constituents.

10. Detailed analyses of waste-waters indicate that polluting toxic materials, heavy metals, and other minerals can be suitably controlled within a sewage system.

## Acknowledgment

Full acknowledgment is made of the generous assistance provided by the many contributors of analytical and other data from the various cities included in these studies.

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# THE OPERATOR'S CORNER

## DIGESTER SUPERNATANT: PROBLEMS, CHARACTERISTICS, AND TREATMENT *

By Stanley E. Kappe

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Disposal of digester supernatant in plants having separate sludge digestion is one that has given considerable trouble, but as a vital part of the sewage treatment process it is one that often is given the least corrective thought.

The process of handling and disposing of digester supernatant liquor at most plants is still in the "horse-and-buggy" stage; improvements since the advent of sewage treatment have been minor. Solution of the problem has been left almost entirely with the sewage plant operator, generally without the proper and necessary tools and facilities.

### Problems

Production of a minimum volume of good digester supernatant liquor with a low solids content is of prime importance for successful and proper digestion and reduction and elimination of supernatant disposal problems. The best method of handling supernatant liquors and solids continues to be one of considerable debate for the plant operator. Some of the arguments and problems are as follows:

1. Disposal on sludge drying beds is only a poor expedient, because it:
   (a) Causes sand beds to clog.
   (b) Limits area available for sludge drying because the solids dry very slowly.
   (c) Produces a breeding place for flies.
   (d) Creates an odor problem.
2. Return of supernatant to the inlet end of a sewage treatment plant without pretreatment:
   (a) Causes primary tanks to become messy, foul, smelly, gaseous, and septic, making them look like the gas vents in Imhoff tanks.
   (b) Provides an additional load on secondary treatment units.
   (c) Causes periodic upsets in treatment and deteriorates the effluents from primary, intermediate, and all types of aerobic treatment plants to a degree depending on the quantity and quality of the supernatant liquor and solids therein.
   (d) Affects the treatability of the sewage and increases the organic load on the stream receiving the plant effluent.
   (e) Causes bulking of sludges in final tanks of standard-rate and high-rate filter plants, and activated sludge plants.
   (f) Creates an odor problem due to the release of dissolved gases as

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sewage-supernatant mixture is applied on standard-rate and high-rate filters or is aerated in activated sludge plants and others using aeration means.

(g) Causes supernatant solids to accumulate and clog filter plants. The upper layer of the stones and the filter sidewalls become excellent breeding places for *Psycoda* flies. The growth on the filter stones takes on a spotty reddish or grayish-green color instead of a uniform dark-green color.

(h) Causes supernatant solids, when mixed with raw sludge, to produce thinner, more voluminous sludges, which take up valuable digester space and which are recirculated so often that after a long, continuous running battle between the operator and the organisms, the sludge, and the insects, the operator finally becomes exhausted. The resulting excess water is pumped to the digester and must leave the digester as supernatant liquor, generally with a high solids content intensifying the disposal problem.

(i) Is responsible for supernatant solids accumulation in primary tanks in a heavy layer with a thickness ranging from a few feet above the bottom to a few feet below the water surface. Some operators refer to this phenomenon as the "floating whale."

(j) Increases the amount of chemicals required and affects chemical coagulation in chemical treatment plants.

(k) Noticeably increases the chlorine demand for prechlorination requirements.

(l) Requires continuous attention to keep the control valves open if the supernatant is returned to the influent at a slow rate throughout the day and night and it is advisable to do so. As an expedient, the plant operator fully opens the supernatant valve, intensifying the load on the plant, and making a mess. Halvorson (1) states that if the dissolved oxygen is exhausted for even moderately short periods of time, aerobic bacteria may die or be retarded in their growth so that secondary treatment ceases to function normally.

(m) Clogs supernatant screens, thus requiring too much water for backflushing.

There may be, and undoubtedly are, many more problems and complaints. According to Lohmeyer (2), supernatant should be returned to a trickling filter only if the plant is considerably underloaded, an opinion no doubt shared by other operators.

In some instances the formation of crystals in channels, on diffuser media, and in supernatant aeration and storage tanks has been observed. These crystals have been identified as magnesium ammonium phosphate ($MgNH_4PO_4 \cdot 6H_2O$). Rawn *et al.* (3) feel these crystals are formed due to loss of $CO_2$ and increase of pH. At pH 8.0 only about 18 ppm of phosphates can be held in solution at 25°C, compared to 305 ppm under conditions existing during the test. Another feeling is that these crystals are formed on diffuser media in the digester supernatant aeration tank by active aeration of saturated unstable solutions.

The quantity and quality of digester supernatant have a marked effect on sludge digestion and on the treatability of raw sewages. The trouble and its effect on the degree of purification are shared almost equally by all types of intermediate and secondary aerobic treatment processes and to a lesser extent by primary and chemical treatment plants. In some plants, the consequences are more noticeable than in others.

*Concentration*

There seems to be agreement that to minimize the problem, the first and most important phase is to pump as little water as possible with the raw sludge to the digester. Excess water must leave the digester as supernatant liquor. This intensifies the treatability problem and increases the solids in the supernatant liquor. The use of raw sludge drawoff inspection wells and sludge concentration tanks has been most helpful if they are used properly. The success differs with each plant and depends on the diligence exercised by the operator in getting solids without excess water to the digester. The smaller the volume, the less disturbance there will be in the digester, and the clearer will be the supernatant liquor.

The method used to concentrate raw sludges, as a means of decreasing the volume of supernatant, has generally followed the same pattern. Raw sludge is drawn from primary tanks, at a frequency depending on the raw solids loading and determined by the plant operator, to a storage or concentration well for separation of the excess water and solids by gravity. The detention period often is as little as ½ hr and sometimes as much as 24 hr.

The concentration tanks at large plants are designed and operated like primary settling tanks on a more or less continuous basis. The tanks are equipped with mechanical sludge collectors, and some also with thickening devices. The overflow goes back to the inlet of the plant and the concentrated sludge is pumped to the digester. Concentration tanks for smaller plants are of hopper-bottom design and are usually operated on the batch principle.

The rate and density of sludge withdrawn from primary tanks is generally controlled by a telescopic valve. At the smaller plants, a similar type valve is generally used to decant the water which accumulates at the surface of the concentration tank. The procedure of sludge withdrawal is satisfactory if the sludge pipe is sized to give adequate velocities to move horizontally and vertically the heavy sludges and grit in the sludges and if the telescopic valve is designed for a drawdown of at least 4 ft. Sludge pipes and telescopic valves that are too large require continuous vertical adjustment to prevent the sludge from settling in the pipe and allowing only filtered water to pass through. Where this occurs, the common solution is to let the valve run at a rate higher than advisable. The operator soon overloads the digester with excess water and inherits the supernatant problems associated therewith.

*Decanting Procedures*

The procedures used to decant water from sludge concentration tanks has not always been satisfactory. At some plants, the gas in decomposing and septic sludge not only retards separation but also causes the sludge to rise to the surface and the water to go to the bottom. One solution consisted of the installation of a vertical well screen similar to the digester supernatant screen, instead of a telescopic decanting valve, in the sludge concentration tank at the sewage treatment plant of the Yale and Towne Mfg. Co. at Philadelphia, Pa. This device has worked satisfactorily. It is readily accessible to inspection and flushing after each use, an added advantage being that the flushing water used to clean the screen goes back to the plant influent and thus does not add excess water to the digester contents. Another solution has been to add to the concentration tank (a) chlorine solution, (b) water with DO content, or (c) compressed air, the purpose in each case being to prevent the sludge from becoming septic and gasifying.

Another innovation meriting attention is that included in the design and construction of the Mt. Alto (Pa.) Sanitorium sewage treatment plant. The sludge concentration tank was de-

signed with heating coils in the bottom. As sludge is drawn into the tank, hot water is circulated through the coils to preheat it and cause the sludge to thicken by rising to the surface through flotation by gases from the decomposing sludge.

Generally, the sludge is heated overnight. The following morning, the water on the bottom of the tank is decanted through a bottom drain and pumped to the plant influent. The heavy sludge remaining is too thick to flow through the sludge lines and must be diluted with primary tank skimmings and broken up by recirculation before it can be pumped to the digester. By experience, the operator has learned how much water to leave or add to the concentrated sludge to maintain excess water at a minimum and yet allow the sludge to flow through the sludge lines for pumping to the digester. The successful experience with this method since 1939 merits attention by designing engineers.

## Characteristics

Digester supernatant has many variations. It varies in color from clear, through different shades of yellow, to an unsightly black. The odor may be pleasant or extremely offensive and nauseating. The BOD, suspended solids, volatile solids, dissolved solids, and oxygen demand may be low or extremely high. Although BOD has been used as an index, the true picture seems to substantiate the old cry: "The trouble is not caused by the BOD *per se*, but by what is in the BOD."

Supernatant from primary treatment plants is generally better than that from secondary treatment plants. This may be because raw sludge from a primary treatment plant is pumped to the digester with a higher solids concentration than that from a secondary-type plant. The larger bacterial content of aerobic treatment plant sludges may be an important characteristic of their supernatants.

Digester supernatant certainly is detrimental to sewage treatment. There is some question as to whether the cause is shock loads or quantity; however, there is no question but that quality is a cause. The answer is to maintain the food (sludge) in a wholesome condition and to promptly and properly dispose of or detoxify the products of bacterial decomposition. The big question is where to begin.

### *Suggested Operational Improvements*

The work which must be done to prevent deposition of solids and putrefaction in the sewer system and sewage treatment plant is known too well to repeat. A large digester with excess capacity has often given results inferior to one smaller or two or more smaller digesters. The requirements for better operation seem to be (a) continuous and thorough mixing of the digested sludge or bacterial seed with the added fresh sludge without deposition so that all of the organic material will be continuously available to the organisms for proper digestion, (b) destruction of the harmful products of putrefaction by bacterial activity or chemical oxidizing and reducing agents so there will be no concentrations in sections of the digester, and (c) maintenance of an environment constantly suitable to proper digestion.

The effects of one organism on the growth of another, (a) by neutralizing its metabolic products, (b) by changing the reaction of the medium in which it grows so as to inhibit further multiplication, (c) by dissolving the other species through its enzymes, and (d) by producing bactericidal and toxic compounds, have long been recognized by bacteriologists for commercial fermentation processes.

### *Fresh Raw Sewage*

There seems to be a similarity in the behavior under treatment of strong fresh domestic sewage, stale and septic sewage and sludge, and bad digester

supernatant. The physical, chemical, and bacterial reactions strongly indicate that the harmful compound from each of these sources is identical.

Strong, fresh raw sewage and relatively clear supernatant have been noted to have the same yellow-brownish cast and strong characteristic odor, which is not evident in easily treated, well-diluted weak, domestic municipal sewage. This same odor is often evident in sick activated sludges and recirculated septic sewage mixtures being distributed on filter beds. The stronger the odor, the more noticeable is the bulking of the sludge in the final tank of activated sludge plants, high-rate filters, and standard-rate filters. The color and strong characteristic odor seem to be caused by the same compound. It affects the treatability of strong, fresh domestic sewages from institutions, summer camps, military camps, and real estate developments, much as stale septic sewages affect normal domestic sewages in some municipalities.

*Bulking Problems*

These fresh sewages should be easy to treat. Experience, however, has been otherwise. The strong fresh sewages have much higher immediate oxygen demands and BOD's than normal domestic sewages and often greater than those of stale septic sewages. The high immediate oxygen demand and BOD, particularly the high dissolved BOD, found in these strong fresh sewages, and likewise in digester supernatant, appear to be caused by a putrefaction compound that bacterial action has not had ample time to decompose to simpler compounds. Investigators have found that they can cause bulking in the laboratory, but not with the materials in normal domestic sewages. Yet sludges allowed to settle and become septic in channels, final tanks, and other units of aerobic treatment structures, like digester supernatant, cause bulking. Is the black color of septic sewages and sludges and digested sludges, and the often seen dark, sick color of aerobic sludges, caused by the same compound? It may be sulfides, but the facts are not conclusive. Halvorson (1) states that the high immediate oxygen demand of digester supernatant may depend on the amount of organic sulfur and/or sulfates in the wastes that can be reduced to sulfides by the action of anaerobic bacteria.

This same harmful but elusive compound apparently makes itself known in another way. Mixed liquors in some activated sludge plants with suspended solids as low as and lower than 300 ppm, like stale septic sewages and strong digester supernatant, have been known to be difficult to aerate and show a DO even when more than adequate oxygenation was being imparted. Normally, there should be no difficulty keeping a high or reasonable DO in mixed liquors of low solids content. Sulfides may play a part, but the characteristic odor present is normally other than that of hydrogen sulfide. During such occasions chlorination is helpful.

Chlorination of mixed liquors and return activated sludges is being used successfully at many activated sludge plants to control bulking. Pre-chlorination is being used also at high- and low-rate filter plants, activated sludge plants, and other type plants with improvements in treatability. At some plants the digester supernatant is chlorinated before discharge to the plant influent, with noticeable improvement in treatability.

At the State College, Pa., Borough plant, and at a few others, instead of decreasing the BOD in the primary effluent, pre-chlorination increased it as much as 100 per cent of that in the raw sewage, even though the removal of suspended solids was normal. Observation of all these chlorination practices indicates that chlorination neutralizes and/or destroys a harmful compound which is identical and the cause of impairment to sewage purification and sludge

digestion. These confusing and interesting observations are challenging and bewildering.

*Search for Interfering Compound*

The first clue as to the possible identity of this harmful product was noted at the State College municipal plant in March 1941. When ferric chloride was added to the mixed liquor in the effluent end of the aeration tanks, the foam therein had a most vivid bluish-violet coloration. At that time all of the problems and reactions previously set forth were much in evidence. The raw sewage was fresh, strong, and yellow-brown in color. The raw sewage, digester supernatant, aerated mixed liquor, and return activated sludge had the same strong characteristic odor, which at times was nauseating, and more so when lime was added. Although there was adequate oxygenation capacity, it was difficult to maintain DO in the mixed liquor, even with plain aeration. The digester supernatant was foul and black, with a heavy suspended solids content. Solids content was the same from top to bottom in the primary and secondary digesters. The activated sludge was bulking in the final tanks and the plant effluent was of inferior quality. Physical changes correcting septicity caused by sludge deposition, plus an increase in oxygenation capacity, and application of chlorine, corrected the difficulties in treatment; but the harmful compound causing the poor digester supernatant and the soupy condition of both digesters remained unidentified.

*Phenols Suspected*

The data collected from a study strongly indicated that the harmful compounds are phenol and phenol derivatives—not from industrial waste discharges, but from bacterial putrefaction of proteins in sewage wastes. Indole and skatole (4), ptomaines, mercaptans, hydrogen sulfide, and other products of bacterial putrefaction may play a contributing part, but the major destructive forces apparently are phenol and phenol derivatives. The reasons are as follows:

1. Phenol gives a bluish-violet color with ferric chloride.
2. Phenol has the strong characteristic odor noted.
3. As a strong antiseptic, phenol suppresses bacterial activity.
4. Phenols are very toxic. The bactericidal property of phenols rises with increase in molecular weight, while toxicity falls off. A substitution of nuclear hydrogen by halogens increases both the bactericidal value and toxicity.
5. Phenols cause death by coagulating the proteins in bacterial protoplasm. In dilute concentrations, coagulation still takes place, but the organisms, like humans, become sick or inactivated to a degree which depends on the concentration. This reaction may be the cause of bulking. The dilute solutions may not be strong enough to kill the bacterial growth, but by gradual absorption the organisms become too sick to function properly.
6. As strong reducing agents, phenols add to the organic load a material that has a high oxygen demand and must be oxidized.
7. Phenols are colorless when pure, but under oxidation they darken through red and brown to black.
8. Phenols can be oxidized by atmospheric aeration and destroyed by chlorine and other oxidizing and reducing agents.
9. Phenols, by oxidation and reduction, can be destroyed by bacterial activity into simple harmless compounds. They are food for some bacteria and powerful bactericides to others.
10. Phenols dissolve in alkali solutions to form compounds giving acid reactions. Chloro- and nitro- derivatives have strong acid properties, not only dissolving in solutions of alkaline hydroxides, but also decomposing carbonates with effervescence, forming

definite and stable salts and regenerating phenols. This behavior no doubt explains the reaction often noticed when lime is added to poor quality return activated sludge and digester supernatant, which gives off with effervescence a characteristic, strong unpleasant odor.

11. Phenols found in sewage sludge mixtures, digester sludges, and supernatants are in sufficient concentration to do process damage.

*Sources of Phenols*

Phenol and p-cresol are formed in the body by putrefaction of food proteins. These are discharged from the body, partly free and partly conjugated in the form of sulfates and glycurates (5). The amount depends on the protein diet of the individual. Total phenol excretion of a normal man averages about 0.2 g per day (6), which is equivalent to 1.06 ppm based on a water usage of 50 gpd/cap. The maximum (7) has been reported as high as 42 mg/ml, which, based on an average daily urine discharge of 1,000 ml and 50 gpd/cap water usage, is equivalent to 224 ppm. Addition of the increment produced by septic stale sewages, by sludges, and by digester supernatants, makes the total substantial.

Unfortunately, proteins are the fundamental product in the formation and constitution of animal and vegetable organisms, and protoplasm of vegetable and animal cells consist of protein substances, which are an indispensable component of human foodstuffs. Therefore, elimination of the proteins apparently cannot be the solution.

Figure 1, prepared from data by Rogers (8), clearly illustrates the powerful destructive forces that can be released by phenols of various concentrations. Unfortunately, when this curve was prepared no data were avail-

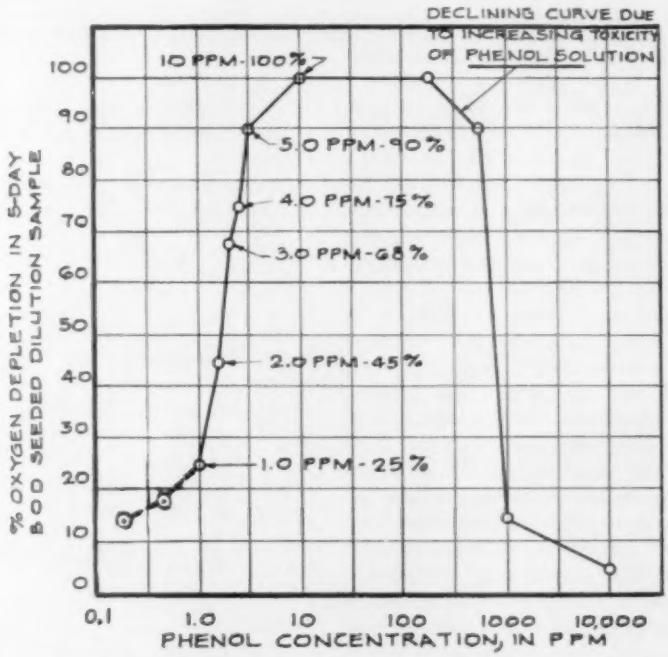


FIGURE 1.—Effect of phenol concentration on oxygen depletion.

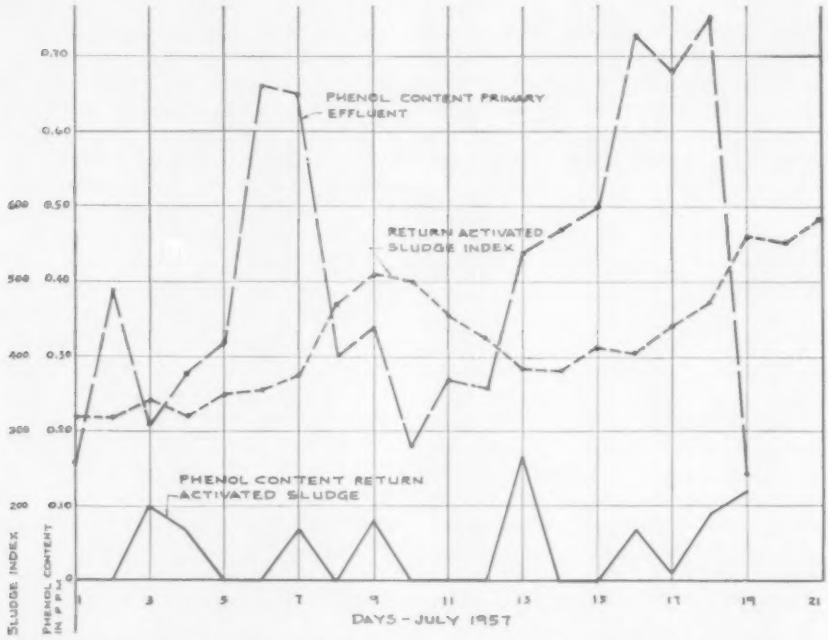


**FIGURE 2.—Daily variation in phenol content of primary effluent and return activated sludge, and return activated sludge index (indication of bulking in final tanks), Mount Alto (Pa.) Sanitorium sewage treatment plant.**

able for conditions from 0 to 1.0 ppm. It should be noted that oxygen depletion is 25 per cent for a 1.0-ppm phenol concentration, and exerts a calculated BOD of 2,250,000 ppm. Since the original curve was prepared tests have confirmed these findings and established the dashed portion.

Phenols were found by Rawn *et al.* (3) in sludge digestion tanks, but their importance apparently was not evaluated. Hoak (9) found 0.072 ppm of phenols in the raw sewage from a large Pittsburgh sewer. This may not have been from industrial waste discharges, as he found an average of 0.264 ppm of phenol imparted to the water by soaking dried oak leaves in sterile distilled water. This phenol may be the one known as catechol, which is found in leaves and sap of certain plants, raw beet sugar, and some resins.

During the March 1941 experience at the State College plant, analyses showed the following phenol contents:

| Sample | Phenol (ppm) |
|---|---|
| Raw sewage | 3.0 |
| Primary effluent | 2.2 |
| Aeration tank effluent | 1.8 |
| Final tank effluent | 1.5 |
| Return activated sludge | 7.0 |

These analyses were made using the Folin-Denis modified method. Unfortunately, no samples of the digested sludge and supernatant liquor were collected. As stated previously, chlorination with other physical changes stopped bulking. Other factors caused a delay of further work.

## Mt. Alto Experiments

### *Phenols*

Recently, experimental work was done at the Mt. Alto, Pa., Sanitorium activated sludge plant.

Phenol determinations were made using the Gibbs method (10) and a spectrophotometer. The phenols in the raw sewage varied during the day and daily up to a maximum of 0.45 ppm. In the digester supernatant they varied with each sample from 0.46 to 0.80 ppm. Figure 2 shows the amounts found in the primary settled sewage and return activated sludge. Bulking in the final tanks, as indicated by the return activated sludge index curve, did not occur at this plant with variations in the phenol content in the return activated sludge, but followed closely the increases in phenol content in the primary effluent. The phenol content in the primary effluent was varied by (a) drawing off all raw sludge from the primary tanks, (b) drawing off less than normal amount, and (c) letting raw sludge accumulate in the primary tanks.

During this period no digester supernatant was returned to the plant. The same conditions of bulking could be produced by heavy discharges of digester supernatant and by storing waste activated sludge in one of the primary tanks, with the settled overflow mixing with the primary effluent.

This curve may not be true in its entirety, because experiments indicated that when 1.0- and 2.0-ppm stock concentrations of phenols were added to raw sludge, digested sludge, and more particularly activated sludges, the added phenol was not fully recoverable. When these same concentrations were added to the filtrates of these sludges, however, the phenol was recoverable. This indicates that the phenols may be chemically fixed by the sludges. Hill and Kelley (5) state that between pH 2.5 and 10.5 the amount of acid or base bound by a protein depends on the chemical composition of the protein, evidencing a chemical-type combination, whereas at pH values outside this range, combination is the same for acids and bases, indicating adsorption.

Figure 2 shows the importance of not allowing deposition of sludges in channels, settling tanks, etc., and the importance of removing sludges from settling tanks promptly. It may also show argument for the advisability of using primary settling tanks with shorter detention periods than are normally used by designers.

Table I gives characteristics of untreated digester supernatant samples collected from primary, high-rate filter, standard-rate filter, and activated sludge plants located throughout Pennsylvania. These phenol tests used the Gibbs method, except that the readings were made with a colorimeter. The results indicate the presence of phenols in the digester supernatant of each plant sampled. The minimum was 0.06 and the maximum 3.0 ppm. The average is about the same for primary and filter plants (0.23 ppm) and for activated sludge plants (0.35 ppm). The high phenol content at the Williamsport, Pa., West plant, which was not included in the average, is no doubt due to industrial waste discharges. Skin, hair, wool, and feathers are allegedly high in proteins. Samples collected near the scum layer could show higher phenols than others.

### *Other Parameters*

It is surprising to note that the BOD and suspended solids for primary treatment digester supernatant and activated sludge plants is about the same and about 50 per cent less than those collected from the high-rate and standard-rate filter plants. These figures are, however, not conclusive. For example, data secured from the Washington, D. C., primary treatment plant records showed that of 64 readings taken at random from the daily reports for 1956, the average BOD was 4,850 ppm, the minimum was 750 ppm, and the maximum was 13,500 ppm; the suspended solids averaged 24,700 ppm, with a minimum of 1,900 ppm and a maximum of 56,800 ppm. Such readings upset the averages and may be due,

as in the case of the Washington plant, to overloaded digesters or valuable space filled with grit. The results show no apparent correlation between phenols, BOD, suspended solids, volatile suspended solids, and total oxygen consumed.

Table II shows the variation that may be expected in oxygen demand of digester supernatant from activated sludge plants. Here again there seems to be no correlation, but only an indication of the range that may be expected in oxygen demands.

Table III shows phenol content in digested sludge with daily fresh raw sludge additions of 50 and 5 per cent, respectively. In both experiments the

**TABLE I.—Raw Digester Supernatant Characteristics**

| Plant | Sample | Total Oxy. Cons. (ppm) | BOD (ppm) | ss (ppm) | Vol. ss (ppm) | Phenols (ppm) |
|---|---|---|---|---|---|---|
| *(a) Primary Treatment Plants* | | | | | | |
| Beaver Falls, Pa. | Digester No. 1, 15 ft from bottom | 340 | 1,880 | 960 | 760 | 0.80 |
| Lewistown, Pa. | Supernatant drawoff | 960 | 760 | 6,450 | 3,900 | 0.20 |
| New Cumberland, Pa. | Supernatant drawoff | 2,525 | 660 | 17,300 | 10,850 | 0.10 |
| Uniontown, Pa. | No. 2 digester | 200 | 244 | 1,420 | 760 | 0.08 |
| | Supernatant drawoff | 150 | 200 | 660 | 420 | 0.06 |
| Williamsport, Pa.: | | | | | | |
| Central plant | Supernatant drawoff | 300 | 250 | 2,425 | 1,400 | 0.12 |
| West plant | Supernatant drawoff | 330 | 1,000 | 725 | 425 | 3.00* |
| Average | | 687 | 713 | 4,277 | 2,645 | 0.23 |
| *(b) High-Rate and Standard-Rate Filter Plants* | | | | | | |
| Gettysburg, Pa. | Supernatant drawoff | 180 | 135 | 1,300 | 900 | 0.06 |
| Bristol, Pa.† | 2nd-stage sup. drawoff | 212 | 320 | 520 | 400 | 0.07 |
| Butler, Pa. | Supernatant drawoff | 840 | 440 | 3,300 | 2,150 | 0.40 |
| Grove City, Pa.‡ | — | 2,400 | 1,480 | 15,500 | 8,800 | 0.50 |
| Clark's Summit St. Hosp. | Supernatant pipe | 5,950 | 6,000 | 32,400 | 17,750 | 0.30 |
| Stroudsburg, Pa. | 7 ft below MLW, dig. No. 1 | 290 | 158 | 1,280 | 760 | 0.18 |
| | 12 ft below MLW, dig. No. 2 | 105 | 136 | 100 | 60 | 0.12 |
| Average | | 1,425 | 1,238 | 7,772 | 4,403 | 0.23 |
| *(c) Activated Sludge Plants* | | | | | | |
| Fairless Hills, Pa. | 2nd-stage digester | 300 | 240 | 4,140 | 2,820 | 0.08 |
| Mt. Alto Sanitorium, Pa. | North digester | 2,450 | 1,250 | 14,650 | 10,650 | 0.64 |
| Norristown, Pa. | Supernatant drawoff | 240 | 100 | 600 | 400 | 0.34 |
| Penn Township, Pa., Long Road plant | — | 220 | 250 | 675 | 525 | 1.00 |
| | — | 315 | 329 | 1,600 | 1,040 | 0.10 |
| State College, Pa. | Supernatant drawoff | 3,200 | 2,700 | 12,100 | 8,800 | 0.08 |
| W. Mifflin Township, Pa., Thompson Run plant | — | 60 | 350 | 100 | 75 | 0.28 |
| York, Pa. | Supernatant drawoff | 170 | 115 | 1,400 | 1,100 | 0.24 |
| Average | | 869 | 667 | 4,408 | 3,176 | 0.35 |

* Not included in average.
† Standard rate.
‡ High rate followed by activated sludge.

TABLE II.—Activated Sludge Digester Supernatant Results

| Plant | Sewage Type | OD (ppm/hr) | | BOD (ppm) | SS (ppm) |
|---|---|---|---|---|---|
| | | Min | Max | | |
| Roanoke, Va. | Ind. and dom. | 1.9 | — | 204 | 317 |
| | | — | 9.4 | 1,104 | 495 |
| Norristown, Pa. | Ind. and dom. | 16.5 | — | 100 | 153 |
| | | — | 16.8 | 320 | 464 |
| Ft. Monmouth, N. J. | Military camp | 4.8 | — | 2 | 166 |
| | | — | 16.8 | 15 | 344 |
| Altoona, Pa. | Ind. and dom. | 21.6 | — | 841 | 508 |
| | | — | 68.4 | 9,200 | 8,500 |
| Mt. Alto (Pa.) San. | Institution | 68.0 | — | 1,250 | 14,600 |
| | | — | 88.0 | 1,600 | 6,000 |

phenol content increased daily until it reached a peak on the 4th day. Up to that time digestion was active; thereafter it was hardly noticeable.

Unfortunately, time did not permit determining how long it would take for bacterial activity to reduce the phenols in the digested sludge so that there again would be no inhibition to digestion. The phenols were run on thoroughly mixed portions of the experimental samples and not on the supernatant. The studies on digestion are being continued.

It also would be of interest to investigate whether there is a connection between periodic sloughing off of trickling filter growth and the amount of phenols absorbed by the growth on the filter stones. It is possible that not all of the phenols are decomposed or detoxified by bacterial activity and that after the phenol content builds up in the sludge to a certain concentration, nature's method of bulking to get rid of the phenols is to slough the growth off the stones.

## Treatment

The methods used to dispose of digester supernatant have in most cases been expedients using the facilities incorporated in the construction of sewage treatment works. Some were well considered by the designers and included as a part of the treatment works. Some were incorporated in the plant structures after the plant was built to correct continuous plant upsets. Some plants, after continuous trouble without choice, have had to use dubious means to get rid of the digester supernatant, often with serious damage to the quality of the water and the aquatic life in the receiving stream.

Some of the methods that are used or that may be used for treatment of digester supernatant are as follows:

1. Sludge drying beds are not advisable for the reasons previously set forth.
2. Lagoons have worked well where the extensive land area required is available and is remote from inhabited

TABLE III.—Phenol Content of Digested-Raw Sludge Mixtures

| Time (days) | Phenol Content (ppm) | |
|---|---|---|
| | Sample 1* | Sample 2† |
| 0 | 0.36 | 0.52 |
| 1 | 0.55 | 0.62 |
| 2 | 0.72 | 0.80 |
| 3 | 0.84 | 0.73 |
| 4 | 0.90 | 0.78 |
| 5 | 0.86 | 0.77 |

* Contains 50 per cent digested sludge and 50 per cent fresh raw sludge, from which each day 50 per cent of the sample was replaced with 50 per cent fresh raw sludge.

† Contains 95 per cent digested sludge and 5 per cent fresh raw sludge, from which each day 5 per cent of the sample was replaced with 5 per cent fresh raw sludge.

dwellings. They are not advisable for built-up areas, due to possibility of odor complaints and, in some cases, mosquito and fly breeding problems.

3. Tank wagon disposal has been used successfully where the haul is short and adequate land area is available for spreading the supernatant-digester sludge mixture on the surface of the ground. This method has been used advantageously by many plants.

4. Disposing of supernatant on lawns around the plant is only a temporary expedient in most cases, but causes luxuriant grass growth.

5. Disposal of supernatant into large bodies of water by dilution is the simplest and most economical method. Unfortunately, only a few plants are located near rivers and oceans large enough to use this method.

6. Sedimentation without treatment is not advisable if the overflow is discharged back to the plant. The phenols and other putrefactive compounds which are produced therein may cause continuous upsets to aerobic secondary treatment plants and may deteriorate the quality of the effluent.

7. Sedimentation with chemical coagulation has not been too encouraging. To control the production of harmful putrefactive compounds and to cut down on the cost of chemicals required, the supernatant should be chlorinated before the coagulants are applied.

8. Centrifuging and vacuum filtration have not been economical up to the present.

9. Use of oxidizing agents, such as chlorine dioxide, potassium permanganate, chlorine, and others, for pre- and direct-oxidation under alkaline conditions (pH around 8.0) bears further investigation and study. Direct chlorination of supernatant under alkaline conditions has been used successfully. At the Abington (Pa.) activated sludge plant it has been found that prechlorination of the raw sewage and aerated supernatant mixture is a "must" when the solids in the supernatant are high and the supernatant aeration period is short. At the Pentagon (Va.) high-rate filter plant, the operator also finds pre-chlorination of the mixture ahead of the pre-aeration tank a "must" when the solids in the supernatant are high.

10. Return of supernatant to the inlet of the plant without pretreatment is an expedient which works well with a good supernatant and when the operator takes the time and effort required to discharge the supernatant at a very low rate throughout the day and night. Otherwise, the operator is faced with the troubles previously set forth. Some proven form of pretreatment is advisable before the supernatant is discharged to the plant, because it is not possible to draw a good supernatant daily and continuously.

11. Pre-aeration periods of 30 min and longer have been found to be most helpful, even though the analyses in Table IV seem to indicate otherwise, showing increases in DO, BOD, suspended solids, and volatile suspended solids. Yet the plant does not work as well when the pre-aeration tank is bypassed. Apparently pre-aeration prepares the food for the aerobic organisms by neutralizing the products of putrefaction in the mixture. Unfortunately, facilities were not available to make phenol determinations at the plants listed. At Ft. McClellan (Anniston, Ala.), experience with a trickling filter was of interest. When the pre-aeration tank (1.0 hr detention time based on daytime flow) was bypassed, the effluent from the standard-rate filter did not show any DO. When the pre-aeration tank was put in service the filter effluent showed a DO of 2.0 to 3.0 ppm, even though the DO in the primary effluent was zero and the plant effluent improved. Pre-aeration also improves materially the settling out in the primary tanks of the solids in the supernatant liquor.

12. Pretreatment of supernatant by aeration has been used successfully at

TABLE IV.—Characteristics of Raw Sewage, Digester Supernatant, and Mixture, Before and After Pre-Aeration

| Determination | Pentagon, Va.* | | | York, Pa.† | | | Wyomissing, Pa.‡ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max |
| Raw sewage: | | | | | | | | | |
| BOD (ppm) | 245 | 202 | 304 | 228 | 205 | 240 | 163 | 120 | 210 |
| ss (ppm) | 228 | 142 | 320 | 208 | 176 | 246 | 240 | 122 | 450 |
| Digester supernatant: | | | | | | | | | |
| OD (ppm) | 7.0 | 4.0 | 11.2 | 2.0 | 1.2 | 3.0 | 3.8 | 3.6 | 4.0 |
| BOD (ppm) | 3,100 | 1,420 | 4,990 | 104 | 87 | 105 | 467 | 400 | 520 |
| ss (ppm) | 8,560 | 5,540 | 15,400 | 645 | 334 | 888 | 1,290 | 940 | 1,600 |
| Vol. ss (ppm) | 5,400 | 2,400 | 10,800 | | | | | | |
| Mixture, raw sew.-dig. sup.: | | | | | | | | | |
| OD (ppm): | | | | | | | | | |
| Before aeration | 4.6 | 3.2 | 7.2 | — | — | — | — | — | — |
| After aeration | 6.0 | 4.0 | 8.8 | 11.6 | 7.2 | 15.6 | 4.5 | 3.6 | 5.0 |
| BOD (ppm): | | | | | | | | | |
| Before aeration | 256 | 196 | 318 | — | — | — | — | — | — |
| After aeration | 290 | 170 | 473 | 257 | 241 | 277 | 364 | 240 | 290 |
| ss (ppm): | | | | | | | | | |
| Before aeration | 290 | 152 | 430 | — | — | — | — | — | — |
| After aeration | 330 | 186 | 450 | 415 | 232 | 650 | 249 | 228 | 292 |
| Vol. ss (ppm): | | | | | | | | | |
| Before aeration | 205 | 104 | 336 | — | — | — | — | — | — |
| After aeration | 235 | 142 | 364 | — | — | — | — | — | — |

* High-rate filter plant, 2-stage; pre-aeration, 30 min.
† Activated sludge plant; pre-aeration, 60 min.
‡ High-rate filter plant, 2-stage; pre-aeration, 30 min.

many plants and should be given serious consideration by designers. The batch system used at the Penn Township plant (Pa.) prevents short-circuiting and its disastrous effects on treatment, and merits attention. The experiments indicated that the phenols often increase for the first 3 hr, sometimes more, and then begin to fall off. Also, that the supernatant aeration tanks should have a capacity of at least 6 hr for the rate supernatant will be withdrawn from the digester, plus 25 per cent for seed sludge capacity. Because the rate of withdrawal often is not closely controlled, batch treatment is advisable. Under this scheme the supernatant aeration tank should have a capacity equivalent to the design daily pumpage of raw sludge to the digester.

Daily, or as required, supernatant should be withdrawn from the digester in the amount of sludge and water pumped into the digester the day before. The supernatant is then aerated 24 hr and the following day all but the 25 per cent kept for seed should be discharged to the plant. This procedure is used at Penn Township, except that generally 6,000 gal of supernatant are mixed with 2,000 gal of activated sludge and the entire contents are discharged to the plant. Supernatant can be discharged ahead of the primary or aeration tanks without effect on treatment. In fact, there has been a marked improvement in treatment since the supernatant aeration tank was built.

The amount of air required is about 3 to 5 cfm per lineal foot of aeration tank length. A spray system is advisable to keep down froth. The amount of supernatant that can be expected seems to be about 1 per cent of the sewage flow, but at some small as well

**TABLE V.—Characteristics of Digester Supernatant, Penn Township (Long Road), Pa., Activated Sludge Plant**

| Sample | Aer. Period (hr) | Tot. Oxy. Cons. (ppm) | BOD (ppm) | ss (ppm) | Vol. ss (ppm) | Phenols (ppm) |
|---|---|---|---|---|---|---|
| (*a*) Sample No. 1 | | | | | | |
| Supernatant drawoff | — | 220 | 250 | 675 | 525 | 1.00 |
| Supernatant and activ. sl. | 0 | 200 | 528 | 810 | 610 | 0.50 |
| | 24 | 125 | 640 | 725 | 475 | 0.15 |
| (*b*) Sample No. 2 | | | | | | |
| Supernatant drawoff | — | 315 | 329 | 1,600 | 1,040 | 0.10 |
| Supernatant and activ. sl. | 0 | 315 | 293 | 1,300 | 990 | 0.13 |
| | 3 | 290 | 290 | 1,300 | 920 | 0.13 |
| | 6 | 290 | 312 | 1,200 | 800 | 0.06 |
| | 25 | 300 | 237 | 1,240 | 860 | 0.06 |

**TABLE VI.—Typical Results During 24-Hr Aeration, Supernatant, Aeration Tank, Penn Township (Long Road), Pa., Activated Sludge Plant**

| Time | ss (ppm) | DO (ppm) | OD (ppm/hr) | Remarks |
|---|---|---|---|---|
| (*a*) Sample No. 1* (2/21/57) | | | | |
| 10:25 AM | 200 | 0 | 1.2 | Black, strong odor, sludge rises |
| 12:05 PM | 200 | 3.8 | 0 | Gray, odor decreasing |
| 2:05 PM | 200 | 6.6 | 0 | Gray, odor decreasing |
| 4:05 PM | 200 | 7.2 | 1.0 | Turning brown, odorless |
| 6:05 PM | 200 | 6.8 | 0.4 | Brownish gray, musty odor, pinpoint floc |
| 8:05 PM | 200 | 6.7 | 0 | Brownish gray, slight odor, floc rises |
| 10:05 PM | 400 | 6.8 | 0 | Brownish, slight odor |
| 12:05 AM | 200 | 9.4 | 0 | Brownish, floc rises |
| 2:05 AM | 200 | 9.3 | 0 | Brownish, floc rises |
| 4:05 AM | 200 | 9.4 | 0 | Brownish, floc rises |
| 6:05 AM | 200 | 8.9 | 0 | Brownish, floc rises |
| 8:05 AM | 300 | 8.7 | 0 | Brownish, no odor |
| (*b*) Sample No. 2† (5/9/57) | | | | |
| 10:25 AM | 1,200 | 4.7 | 0.6 | Black, strong odor, sludge rises |
| 12:25 PM | 1,200 | 5.6 | 0.3 | Brownish, slight odor, settles rapidly |
| 2:25 PM | 1,200 | 7.0 | 0 | Brown, odorless, settles rapidly |
| 4:25 PM | 1,200 | 9.4 | 0 | Brown, odorless, settles rapidly |
| 6:25 PM | 1,100 | 9.8 | 0 | Brown, odorless, settles rapidly |
| 8:25 PM | 1,200 | 10.1 | 0 | Brown, odorless, settles rapidly |
| 10:25 PM | 1,200 | 10.4 | 0 | Brown, odorless, settles rapidly |
| 12:25 AM | 1,100 | 14.0 | 0 | Brown, odorless, settles rapidly |
| 2:25 AM | 1,100 | 14.2 | 0 | Brown, odorless, settles rapidly |
| 4:25 AM | 1,100 | 11.8 | 0 | Brown, odorless, settles rapidly |
| 6:25 AM | 1,100 | 12.0 | 0 | Brown, odorless, settles rapidly |
| 8:25 AM | 1,100 | 9.9 | 0 | Brown, odorless, settles rapidly |

* 6,000 gal digester supernatant liquor only.
† 6,000 gal digester supernatant, 2,000 gal waste activated sludge.

as good-sized plants, it has been as high as 4 and as low as 0.05 per cent. The amount from primary treatment plants seems to be generally much lower than that from aerobic secondary treatment plants, but again depends on the operator. Table V shows the effect 24-hr aeration had on digester supernatant at the Penn Township Long Road activated sludge plant. The supernatant liquor is low in BOD and suspended solids; by comparison with others it is very good. Yet, when unaerated its discharge to the plant caused continuous periodic upsets. Aerated, it eliminated plant upsets. The analyses indicate some, but no significant decrease in total oxygen consumed, BOD, suspended solids, and volatile suspended solids, but they do show a marked decrease in phenols (1.00 to 0.15 ppm and 0.10 to 0.06 ppm) which is noteworthy and is additional substantiating evidence as to the identity of the harmful compound in digester supernatant which causes plant upsets. Table VI, taken from the plant log, shows that the digester supernatant after 2- to 4-hr aeration changes in color from black to activated-sludge-brown, and in one of the two samples settled rapidly after 4-hr aeration. The change in color and the settling rate can be expected to vary daily, depending on factors still under study. However, the phenols generally began to fall off after 3-hr aeration.

13. Studies by the Texas Engineering Experiment Station (9) indicate that two-stage trickling filters could be used for treatment of digester supernatant liquors. The results indicate considerable reduction in BOD and suspended solids and an increase in nitrates at low dosage rates on digester supernatant containing 1,800 ppm BOD and 1,100 ppm suspended solids. Chamberlain (11) indicates that treatment with anthracite contact filters and trickling filters with backwash facilities was not satisfactory for heavy supernatant liquors because of the frequent backwashing required.

14. Preliminary studies indicate it may be advisable to partially or completely reduce and/or concentrate aerobic sludges (such as waste activated sludge and filter sludges) by aerobic digestion before discharge of these sludges to the plant or directly to the digester.

## Conclusions

1. Sludge concentration tanks of proper design and with proper and adequate decanting facilities should be required for each sewage plant. They should be operated effectively in conjunction with the primary sludge draw-off facilities to concentrate raw sludge and keep to a minimum the excess water pumped with the sludge to the digester, thus minimizing the digester supernatant disposal problem and improving digestion.

2. Some factors that influence good characteristics of digested supernatant are: (a) functional design of digester and facilities provided to continuously and thoroughly mix fresh solids with seed sludge or digested sludge to prevent putrefaction; (b) character of raw sludge (fresh, stale, or septic); (c) effectiveness of grit chamber to keep undue amounts of inert material from occupying valuable digester space; (d) temperature of digestion; (e) rate and frequency of sludge pumping; (f) character of raw sewage (industrial, domestic, etc.); (g) effectiveness of sludge concentration; (h) type of roof (fixed or floating); (i) loading; (j) facilities to continuously break up scum; and (k) proper environment.

3. Untreated digester supernatant should be discharged to the plant at as low a rate as possible throughout the day and night.

4. Digester supernatant should be given adequate and proper pretreatment before it is discharged to the sewage plant.

5. Phenols and phenol derivatives seem to be the main destructive force in digester supernatant that causes plant upsets. The source of the phenols is

not industrial waste discharges, but putrefaction of proteins, beginning in the human body and continuing in the sewage system. The phenol content also seems to affect digestion.

6. Elimination of the destructive force of phenols is possible by aeration, preferably with compressed air, oxidizing and reducing agents, and bacterial activity, singly or in combination under proper conditions.

7. If untreated digester supernatant is discharged to the plant, the treatment units should be designed to take care of this loading.

### Acknowledgments

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# SEWAGE CHLORINATION CONTROL THROUGH USE OF THE OXIDATION-REDUCTION POTENTIAL*

BY F. MORLEY WEIR

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Controlling the chlorination of sewage to sub-residual levels can accomplish a major saving in the quantity of chlorine used. Basis of the control is measurement of the oxidation-reduction potential. Generally this term is abbreviated to O-R-P and is known as the redox potential. It is possible to comprehend the capabilities and limitations of such a control system or to operate the necessary equipment without consideration of the fundamental electro-chemical theories governing the system. However, it seems desirable to touch briefly on the theory.

* Presented at the 1956 Annual Meeting, California Sewage and Industrial Wastes Assn.; Santa Rosa, Calif.; Apr. 25–28, 1956.

## Theory

In the early days of chemistry it was believed that a certain class of chemical reaction required oxygen in some form. Accordingly, it was termed oxidation. The material that reacted with the oxygen was said to be oxidized or to be a reducing agent. As the knowledge of chemistry increased it became apparent that similar types of reaction occurred in which no oxygen was involved. It was further determined that this type of reaction required a change in the electrical charge of the reactants. Accordingly, a more fundamental definition of oxidation reduction was developed. Oxidation of a material is now defined as a gain in positive charge by the material oxidized. The other element is caused to be reduced and can be termed a reducing agent.

As an example a reaction that often occurs in sewage is the oxidation of hydrogen sulfide by chlorine. The reaction can be written

$$H_2^+S^= + Cl_2 \rightarrow 2H^+Cl^- + S$$

The sulfur has gained in positive charge or has been oxidized by the chlorine.

Because electrical charges are involved it was considered possible to relate the chemical reaction to the electrical energy. A chemically inert electrode in a solution was found to assume a potential or voltage. If this potential is compared with that of a reference electrode which produces a constant potential, the result is known as the oxidation-reduction potential.

## Application

Most commercial applications of the oxidation-reduction potential as a control use gold or platinum measuring electrodes and a standard calomel cell as the reference electrode. In initial experiments for sewage control, it was found that insensitivity soon developed due to coating of the electrode with grease or slime. As a result, a measuring cell which uses a pool of mercury for a measuring electrode and a silver-silver chloride reference electrode was developed for sewage applications.

Either of two systems of control may be employed. In one case the rate of chlorination is determined entirely by the O-R-P. In the second system the chlorinator is controlled by a flowmeter to follow the changes in the rate of flow of sewage. The O-R-P in this case is superimposed on the volumetric control and is concerned only with compensating for changes in chlorine demand.

Any control system has certain limitations and certain capabilities. Since mercury is usually used as an electrode, the cell cannot be used when there is a high cadmium content in the waste because cadmium will poison the mercury. Also the mercury electrode cannot be used for control of chlorination where it is necessary to carry an orthotolidine residual because at this level of dosage the chlorine reacts with the mercury to form mercurous chloride, thereby causing insensitivity. With a mercury electrode, the O-R-P is ideally suited to control of chlorination to sub-residual levels.

It appears that sub-residual chlorination is effective in odor control, prevention of concrete disintegration, sewage conditioning for improved settling, and for final chlorination where conditions are such that maximum bacterial reduction is not required. The most effective way to control at sub-residual levels is by means of a control using the O-R-P. On the other hand, sporadic underchlorination of wastes containing hydrogen sulfide can cause severe disintegration of concrete.

## Economics

It is impossible to arrive at an exact evaluation of the economy of control by use of the oxidation-reduction potential, because it is impossible to arrive at an exact dollar value for satisfactory odor control and sewage

conditioning. If the highest degree of control is required it has generally been the practice to pre-chlorinate to a small residual in order to insure sufficient chlorine dosage. Odor control that would be adequate in most instances could be accomplished at sub-residual levels.

In the smaller installations it is common practice for the treatment plant to be unattended completely or have only casual supervision during 12 to 16 hr per day. With this type of supervision radical changes in chlorine demand often occur at times in the day when the chlorine rate cannot be changed manually.

It is possible in many installations to save up to 25 per cent of the cost of chlorine. In large plants this can effect appreciable savings. At San Diego, Calif., 1 ppm represents an annual cost of $5,000. With the usual chlorine application of 5 to 15 ppm, a 25 per cent reduction would be quite attractive.

In addition to the direct savings in chemical costs, other important benefits may be received. High demand conditions may exist periodically for relatively short periods of time. With constant rate chlorine dosage, plant odors may become objectionable and cause an unfavorable public reaction to a plant that is normally doing a satisfactory job.

At San Diego O-R-P equipment will control final chlorination. The effluent discharges into San Diego Bay where considerable dilution occurs. It appears that sub-residual chlorination may provide sufficient bacterial kill to make the effluent acceptable at this particular location. Even if sub-residual control can be used for only a portion of the year, it can effect considerable chemical savings alone.

Certain phases of sewage chlorination can be controlled more economically and more efficiently by the application of the O-R-P than by any other method presently available.

## TIPS AND QUIPS

### Significance of Irrigation

It is now reported in the United States that 30 million acres of land, or about two-thirds of the area that can be irrigated, are now being provided with irrigation water.

The last frontier for irrigation, the so-called humid east, has shown an increase of 55 per cent in irrigated land during the last eight years. At the present time it is estimated that there are 3 million acres under irrigation in 31 eastern states.

While these figures represent estimates from agricultural sources, the use of irrigation is becoming a significant factor to those concerned with sewage and industrial waste treatment. Certain areas now utilize sewage effluent for crop irrigation and this practice is increasing. Irrigation for a number of industrial wastes (mostly within the 31 humid states) has become the bread-and-butter disposal method. In many instances, if spray irrigation had not been adapted to this problem, the industry would have closed its doors, either permanently or in order to relocate.

### Confusion Unlimited

Moscow radio says the U.S.A. is a hysterical, topsy-turvy country, where people eat upside-down cake, doors go around in circles, and everybody has an inside-out house. Wait 'til they try to decipher some of the "cool" talk of the American teen-agers.

## Short Cuts in Flame Photometry

For you analysts it is good to know that one of the more time-consuming tasks is gone. There are now available six prepared accurate standards for flame photometry.* All chemicals used meet ACS specifications, and preparation is made with rigid controls.

The following cations are available in the stated solutions:

| Cation | Concentration (mg/ml) | Equivalent to: (ppm) |
|---|---|---|
| Sodium | 0.1 | 100 |
| Potassium | 0.1 | 100 |
| Lithium | 0.1 | 100 |
| Calcium | 0.2 | 200 |
| Magnesium | 2.0 | 2,000 |
| Barium | 2.0 | 2,000 |

For lower concentrations, simply dilute with water deionized or triply distilled (over permanganate).

## Quick Couplings †

A new line of quick connect and disconnect couplings is being introduced (Figure 1). Some of the features are: interchangeability with other couplings, greater flow, less pressure drop, and small rugged compact design. Sizes are ¼, ⅜, ½, and ¾ in., with working pressures up to 10,000 psi.

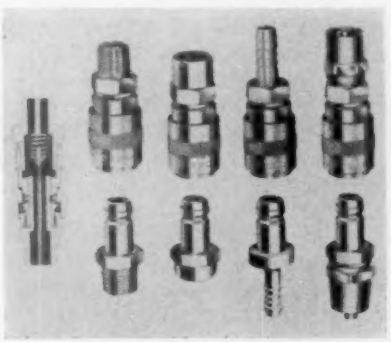


FIGURE 1.—Quick connect and disconnect couplings for high-pressure service.

A simple connecting manipulation is featured. The coupling locks automatically without turning or twisting. Full 360° swivel action reduces pneumatic tool operator fatigue and eliminates troublesome hose kinking.

The interchangeability of these couplings makes possible replacement of either coupling sockets or plugs, without changing or having separate air lines to existing production equipment.

## What's Left?

A tractor-trenching device ‡ that digs trenches for sub-surface drainage systems, forms pipe from a plastic sheet, and backfills the hole, is a recent development. It is reported that pipe can be laid by this system at a quarter of the cost of current methods.

The potential uses of such a procedure in the sewage and industrial waste field are very interesting indeed.

## Sewer Construction Difficulties §

Interesting construction problems are reported from Glen Ellyn, Illinois. Population increases made necessary a sewer extension project as a relief for existing overloaded sewers. Along the entire five miles of sewer construction the contractor had to lick the problem of peat soil in the trenches. The problem was solved by removing the peat and replacing it with crushed stone or reinforced concrete cradles.

Differential settlement also created a problem. Because settlement on each side of the pipe is greater than that directly over it, downward movement of the backfill actually increases the load on the pipe. This was minimized by narrow trench excavation.

* Fisher Scientific Company, 711 Forbes Ave., Pittsburg 19, Pa.

† Perfecting Service Company, Charlotte, N. C.

‡ Building Research Institute, National Research Council, Washington, D. C.

§ From *Clay Pipe News*, **24**, No. 1.

# Editorial

## DETROIT—1958

Again it is time to note carefully the time and place for the 1958 Federation Meeting—October 6–9, 1958, at the Sheraton-Cadillac Hotel, Detroit, Mich. The general convention announcement for the 1958 meeting, with its hotel reservation card, should be in your hands by the time you receive this issue of the JOURNAL.

Again the Federation will be the guest of the Michigan Sewage and Industrial Wastes Association, as it was a decade ago. At the time of the previous Detroit Meeting in October 1948, the Federation was growing at a rapid rate, along with most other postwar activities. While "Industrial Wastes" had not been added to the name, there was a growing interest in this field and the program then was showing this influence. Exhibitors were showing their finest wares and the postwar boom was in full swing.

During these ten years, steady development, growth, and changes have occurred in the Federation as an organization and publisher of SEWAGE AND INDUSTRIAL WASTES. During this decade growth has increased 67 per cent, based on an estimate of Federation membership of 8,000 on September 30, 1958. Further growth has been indicated in the convention program by the increase from six to the nine technical sessions scheduled for the 1958 meeting. The demand for exhibit space has likewise grown, as evidenced by a 37 per cent increase in the number of exhibitors during the 10-yr period. This has created a sellout in 1958, with all booths spoken for on the date of assignment.

It is hoped that the Detroit Meeting will attract people from all parts of the world. With the Federation's growth to include New Zealand and Israel at the 1957 Board of Control Meeting, attendance is in order and most welcome from every quarter of the globe.

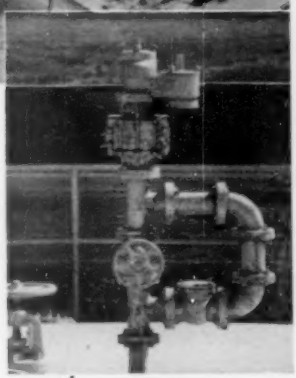
While Detroit is generally known as the Motor City, it is also the acknowledged center of much other industrial activity. To those concerned with the treatment of sewage and industrial wastes, this means not only population growth and the attendant sanitary sewage problems resulting from it, but treatment of industrial wastes for the prevention of water pollution and preservation of water resources. As given in more detail in the convention flyer, inspection trips will be made to the Detroit Sewage Treatment Plant as well as to industrial waste treatment plants in the area.

Both you and your wife will be greatly pleased if you bring her to the Detroit Meeting with you. The Local Arrangements Committee has provided ladies' entertainment that is possible only in the great center that Detroit is. Attractive features of unusual distinction will be available for the ladies to enjoy during "Federation Week" in Detroit.

The 1958 Federation Meeting in Detroit promises to be not only the greatest meeting of the year in the sewage and industrial wastes field but it is likely to be the greatest meeting in the field to date. Note the dates—October 6–9, 1958—and send your hotel reservation card in now.

R. E. F.

Photos courtesy Dorr-Oliver



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S-16

# Proceedings of Member Associations

## MISSISSIPPI SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 1st Annual Meeting of the Mississippi Sewage and Industrial Wastes Association was held in the Robert E. Lee Hotel, Jackson, Miss., on March 7, 1958. Registration totaled 73 and attendance numbered approximately 80.

The technical program was excellent and featured the following papers:

"Operation and Maintenance of Sewage Treatment Plants," by George T. Lohmeyer.

"Treatment of Metal Finishing Wastes," by H. Fred Martin.

"Aerial Survey Methods and Their Relation to Sewage Works Projects."

"Waste Stabilization Ponds," by Joe K. Neal.

The speaker at the luncheon meeting was Kenneth S. Watson, President of the Federation of Sewage and Industrial Wastes Associations. Mr. Watson is Consultant, Water Management and Waste Control, General Electric Co., Schenectady, N. Y.

Attendance at both the technical session and the luncheon was excellent and exceeded the total membership in the association. During the meeting ten new members joined the association.

At the business meeting of the as-

*(Continued on page 280a)*

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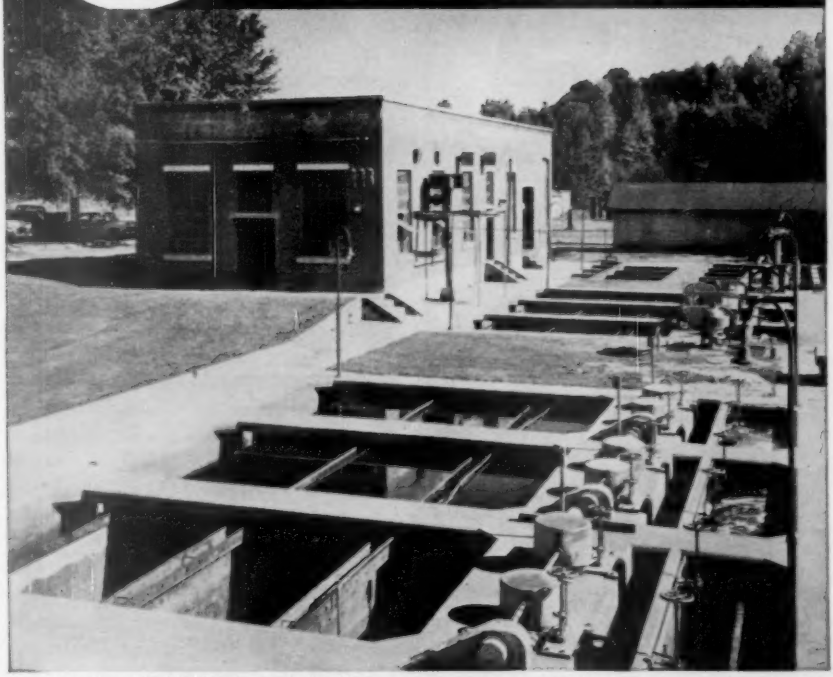

Rex Verti-Flo Clarifier in Gastonia, N.C., sewage treatment plant. Walter Gardner, plant chemist.

With the aid of Rex Verti-Flo Clarifiers, the city of Gastonia, North Carolina, substantially increased the capacity of its sewage treatment plant *without increasing the plant size*... solved the problem of a badly overloaded plant. Installed in the existing settling tanks, Verti-Flo provided the increased capacity needed... at low cost. Here's why!

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sociation, the following officers were elected to serve during 1958–59:

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*Secretary-Treasurer:* Robert A. Gerber, Jackson.

ROBERT A. GERBER,
*Secretary-Treasurer*

## NEW YORK SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 30th Annual meeting of the New York Sewage and Industrial Wastes Association was held at the Belmont Plaza Hotel, New York, N. Y., January 23–24, 1958. Registration totaled 334 members and guests and set a new record in attendance. The previous record was set in 1957 when 308 members and guests were present.

The technical sessions featured papers on the following subjects: responsiblity for operator training; modification of storm and industrial wastes systems at General Electric Company, Schenectady, N. Y.; industrial wastes surveys and treatment, Niagara Dupont plant; sewage treatment at New York state institutions; water pollution control on a recreational watershed; developments relating to the enforcement of the New York State Water Pollution Control Program; sewage treatment at West Point; and rates of transpiration for sewage disposal by transpiration.

One of the highlights of the meeting was a symposium on package plants for sewage treatment. J. J. Baffa, Consulting Engineer, New York, N. Y., directed the panel discussion. Participating were: J. D. Cohen of the Chicago Pump Co., W. L. Berk of Yeomans Brothers Co., F. R. Burde

(*Continued on page 282a*)


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# Equipment and Supply Lines

**Chemical Feed Pumps**—Catalog No. 10.0 presents technical information on sealless plastic and stainless steel pumps for pumping chemicals, such as ferric chloride. A variety of liner materials is available for quick installation in the pumps.—Vanton Pump and Equipment Corp., 201 Sweetland Ave., Hillside, N. J.

**Chromatographic Apparatus**—Information is available on a complete line of analytical distillation and chromatographic apparatus for research work.—Podbielniak, Inc., 341 East Ohio St., Chicago 11, Ill.

**Non-Clog Pumps**—Information on a new line of "Mono-Vane" non-clog pumps is available upon request.—Aurora Pump Division, The New York Air Brake Co., Aurora, Ill.

**Sewage Shredders**—Catalog S. G. 10 describes a line of shredders for use with self-cleaning bar screens.—Gruendler Crusher and Pulverizer Co., 2915 North Market St., St. Louis 16, Mo.

**Portable pH Recorder**—A portable, self-contained pH measuring and recording instrument is available for field survey work.—The Bristol Co., Waterbury 20, Conn.

**Flowmeter**—A new 4-page booklet is available on the Laub electro-caloric flowmeter. The meter is smooth bore and operates on a thermal principle (rate of heat transfer).—Industrial Development Laboratories, Inc., 17 Pollock Ave., Jersey City 5, N. J.

**Special Valve**—A cushioned emergency cut-in valve which opens automatically in an emergency is described in Bulletin W-14.—Golden-Anderson Valve Specialty Co., 1232 Ridge Ave., Pittsburgh 33, Pa.

**Clay Pipe**—A new bulletin describes "Wedge-Lock" clay pipe.—Robinson City Products Co., 65 West State St., Akron 9, Ohio.

**Paint Additive**—A paint additive which reportedly imparts an effective germicidal and fungicidal property when added to most paints has been announced. The additive is claimed to control bacteria and fungus as long as 6 to 12 months after application. Active ingredient is a new complex organic chemical of the triazine family. Trade-named "Nuozene," the product is currently available in 100-lb lots.—Heyden Newport Chemical Corp., 342 Madison Ave., New York 17, N. Y.

**Conveyor**—Bulletin 550-P5 describes the "Conveyoflo" meter for continuously weighing and controlling belt-conveyed materials. It is applicable to sludge drying facilities and chemical conveyors.—Builders-Providence, Inc., 345 Harris Ave., Providence 1, R. I.

**Safety Equipment**—New illustrated Catalog 10 presents an entire line of safety equipment, complete with general specifications, illustrations, and recommended uses. Equipment is grouped according to function.—General Scientific Equipment Co., 7516 Limekiln Pike, Philadelphia 50, Pa.

**Pumps**—Two new descriptive brochures are available describing vertical non-clog sewage pumps (Catalog F-100), and 3- and 4-in. non-clog sump pumps (Catalog E-101).—Economy Pump Division, C. H. Wheeler Manufacturing Co., 19th St. and Lehigh Ave., Philadelphia 32, Pa.

**Pneumatic Ejectors**—A new line of pneumatic sewage ejector systems is described in Bulletin No. KSM-1. The new ejectors have capacities varying from 20 to 600 gpm at discharge heads, ranging from 10 to 40 ft. They are available in cast iron or welded steel, as single or twin units. Electrode, pneumatic, or electric float switch controls are available.—Komline-Sanderson Engineering Corp., Peapack, N. J.

of Dravo Corp., W. M. Gross of Infilco, Inc., and C. A. Knapp of Dorr-Oliver, Inc.

The guest speaker at the luncheon meeting was Mr. Merrill Eisenbud, Manager, New York Operations Office, United States Atomic Energy Commission. His topic was "Recent Developments in Civilian Application of Atomic Energy."

The Bedell Award was presented to Raymond W. Hess, Buffalo, N. Y. and the Hatfield Award to Uhl T. Mann, Baldwinsville, N. Y.

The following Memorial Awards were presented for outstanding association papers:

The Kenneth Allen Award to W. Wesley Eckenfelder, Jr., and Norman Melbinger for their paper on "Settling and Compaction Characteristics of Biological Sludges" (THIS JOURNAL, **29**, 10, 1114; Oct. 1957).

The Lewis Van Carpenter Award to John Laird for his paper on "Sludge Digester Operation at Brighton, New York" (THIS JOURNAL, **30**, 1, 107; Jan. 1958).

The Charles Agar Award to A. Gordon Wheler and D. E. Stearns for their paper on "Sewage Treatment for Housing Subdivisions."

At the annual business meeting the following officers were elected:

*President:* Francis J. Cramer, Rochester.
*Vice-President.* S. W. Steffensen, New York.
*Treasurer:* J. C. Brigham, Albany.
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(Continued through page 290a)


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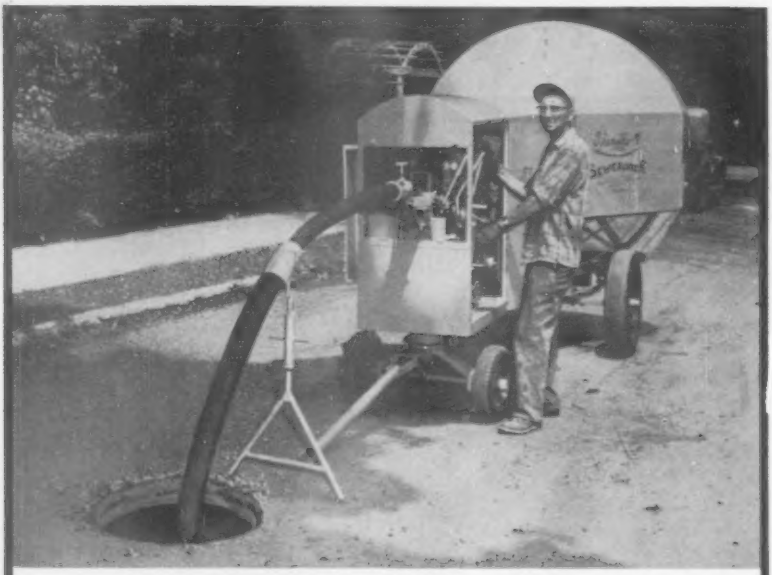

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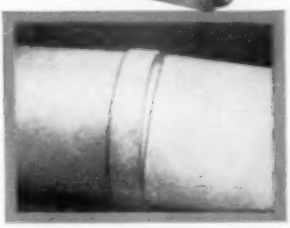

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